The relationship between technology and equity has only recently become a matter of concern to governments and international lending institutions, however, and the complex interactions between technical change and social benefits are but dimly understood. Nevertheless, social equity must become an increasingly important criterion in public investments in the years ahead or the choice of technologies will only widen the gulf between rich and poor.

Energy Considerations

Cheap and abundant fossil fuels have played a central role in most of *the key technological developments since the Industrial Revolution.* But that role has been particularly evident during the past few decades. The virtual doubling of global agricultural production between 1950 and 1975 relied heavily on the use of energy-intensive chemical fertilizers. Projected shortages of important minerals have been averted by new technologies that have harnessed increasing amounts of energy to mine and process low-grade ores. And spectacular increases in labor productivity—the basis for unprecedented global economic growth in the postwar era—have largely been achieved with mechanization technologies that replaced human and animal muscle power with fossil fuels.

Most of these technological developments took place when a barrel of oil cost 15¢ at the wellhead and less than $2 on the international market. Cheap oil and gas consequently became the lifeblood of modern industrial society, rising from only 16 percent of the world's commercial energy budget just 50 years ago to about two-thirds of it today. In addition to providing an immense subsidy for agricultural and industrial production, cheap oil profoundly shaped physical and social environments during the past generation. It gave birth to the concept of planned obsolescence; provided inexpensive transportation that changed the face of cities, towns, and the countryside; and helped fuel rising expectations of material wealth. With little incentive to husband energy resources, energy-intensive technologies proliferated, and economic planners paid little attention to the efficiency with which energy was used.

When oil and gas were cheap and plentiful, the marriage between petroleum and modern technology was scant cause for concern. Indeed, as technological advances had overcome food and materials shortages in the past, they were being counted on to avert energy shortages in the future. The vehicle for such hopes has long been nuclear power, whose proponents once confidently promised virtually unlimited energy at prices that would undercut even those of oil and gas. But complacency about energy supplies has been rudely dispelled in the seventies. The 1973-74 Arab oil embargo and the fivefold rise in world oil prices during the following four years marked an abrupt transition from a period of abundance to a new era of rising energy costs and uncertain petroleum supplies. Barring another embargo, the global economy is not on the verge of grinding to a halt because of oil shortages, but the long-term prospects for cheap energy are not good.

Global oil and gas production is expected to peak in the nineties, and to decline steadily thereafter. Some projections have even indicated that oil shortages could develop in the early eighties if key reserves become seriously depleted. Nuclear power has run into myriad problems, among which steeply rising costs, the lack of permanent waste disposal facilities, and fears of weapons proliferation loom large. And a massive switch to coal could have unacceptable health and environmental costs, including the alarming possibility of irreversible changes in the earth's climate resulting from a buildup of carbon dioxide in the atmosphere.[41]

With oil shortages projected, and large question marks hanging over nuclear power and coal, there is an urgent need to develop and deploy technologies that make use of renewable energy resources—direct sunlight, running water, winds, and plant materials. Equally urgent is the need to pay close attention to the efficient use of energy. A good example of how cheap energy influenced technological change—and how rising energy prices and potential scarcities of oil and gas may affect future developments—can be found in the food production and distribution systems of advanced industrial countries.

In traditional agricultural systems, where human labor provides the only source of energy for tilling, planting, weeding, and harvesting, the energy contained in the crops must exceed the energy used in their cultivation—if not, agriculture would be unable to sustain traditional farming communities. Thus, slash-and-burn cultivation of corn in parts of Latin America produces about five kilocalories of

> **"About 1,150 kilocalories of fossil fuel energy are needed to ship one pound of vegetables from California to New York."**

food energy for every kilocalorie of energy spent in the fields. Wet rice agriculture in parts of Asia offers even better energy returns: each unit of energy invested in cultivation yields between 10 and 15 units of food energy.[42]

At the other end of the scale, the highly mechanized farms of the United States, the Soviet Union, Europe, and Japan rely on fossil fuels for most of their energy requirements. According to David Pimentel of Cornell University, the equivalent of 80 gallons of gasoline is now used to raise an acre of corn in the United States, and every kilocalorie of energy used in the cultivation produces only about two kilocalories of food energy. Moreover, if the corn is then fed to cattle in feedlots, the energy balance is tipped the other way—at least ten units of energy are invested for each energy unit contained in beef.[43]

The availability of cheap energy for the production of fertilizers, pesticides, and herbicides meant that yields could be raised without greatly increasing the land in cultivation. Corn yields in the United States have in fact more than doubled over the past 30 years, largely because of a 16-fold increase in fertilizer use. Cheap fossil fuels replaced human and animal power in industrial countries through the use of tractors, combine harvesters, electric pumps, and other agricultural machines. As a result, the proportion of the population employed in agriculture in the United States dropped by half between 1920 and 1950, halved again by 1962, and since then has dropped yet again by 50 percent. Only about 4 percent of the American labor force is now employed directly in the fields.[44]

In a society where only a tiny fraction of the population remains on the land, vast amounts of energy are required for food storage and distribution. In the United States, about four times as much energy is used to transport, process, store, sell, and cook food as to produce it. Production of some foods has become concentrated in specific regions. Commercial vegetable production, for example, is now concentrated in California and Florida, although only a few years ago New Jersey supplied a substantial portion of the vegetables marketed on the East Coast. About 1,150 kilocalories of fossil fuel energy are needed to ship one pound of vegetables from California to New York. That is more energy than most vegetables contain.[45]

Such energy accounting does not imply that the world must revert to traditional agricultural practices because of potential fossil fuel shortages. But it does suggest that Western-style food systems have become excessively dependent on fossil fuels, and that they are not suitable models for most developing countries to follow. If the world's population were fed an American diet, produced with U.S.-style food technologies, production and distribution alone would use up all known global oil and gas reserves in just 13 years. Similarly, if India were to convert its agricultural system to American methods, agriculture alone would require fully 70 percent of the commercial energy that is now used for all purposes in that country.[46]

The energy balance of Western food systems suggests that the chief inefficiencies occur after the food leaves the farm gate. Perhaps the most egregious inefficiency is the use of a two-ton automobile to carry a ten-pound bag of groceries from the supermarket. Excessive processing, transporting, and packaging uses vast amounts of energy that might be saved by less centralized food production and distribution. Urban gardening, solar-heated greenhouses in urban and suburban areas, and greater use of refillable containers in grocery shops would all help make the food system in developed countries less energy-intensive.

Although changes in processing and distribution offer the best prospects for improvements in the energy efficiency of the food systems of most countries, there is considerable scope for improvement on the farm as well. Energy used to produce chemical fertilizers is now the chief energy input into American agriculture, accounting for more fossil fuel than the gasoline used to power tractors and other farm machines. Chemical fertilizers have taken over almost completely from the manures and leguminous plants that were used as fertilizers just a few decades ago, a substitution made economically attractive by cheap oil and gas. As energy prices rise, however, the economic balance may again favor more extensive use of traditional fertilizers.[47] The use of sewage sludge could also reduce requirements for chemical fertilizers, provided serious questions about the contamination of sludge with heavy metals can be resolved. In addition to saving energy, more extensive use of organic fertilizers like manure would help improve the condition of seriously depleted soils, while recycling sewage sludge on farmlands would reduce the capital and energy costs of constructing new sewage treatment plants.[48]

Not all traditional technologies are energy-efficient. The technology of cooking over an open fire—common in many Third World villages—evolved when firewood was abundant and supplies seemingly inexhaustible. But like the use of oil in the industrial world, current patterns of firewood use cannot be sustained indefinitely. In many parts of the Third World, the countryside has been stripped bare of trees, creating a severe energy crisis for hundreds of millions of people, driving up the price of firewood, and causing serious soil erosion problems. Reducing the demand for firewood by improving the efficiency with which fuel is used in cooking could therefore bring benefits even beyond those of saving energy.[49]

Cooking over an open fire requires more energy than cooking over a gas or electric stove because about 90 percent of the heat is wasted. According to energy analyst Arjun Makhijani, the efficiency of traditional Indian cooking stoves could be doubled for an investment of about $10 a stove, saving a family $10-$25 a year in firewood costs. Similarly, a mud stove has been developed in Guatemala that requires only half the wood used in cooking over an open fire. The stove, which costs less than $10, also warms the house and heats water with waste heat. It produces a significant health benefit as well: it replaces the traditional practice of lighting a fire in the middle of a chimneyless room, a practice that promotes lung and eye diseases.[50]

In many developing countries there is substantial room for improvement in the efficiency with which draft animal power is used. Draft animals, the chief power source for cultivation throughout Asia, provide 12 times as much power in India as do tractors, for example. They convert renewable energy sources—roughage from grasslands—into useful work. But their efficiency is often impaired on two counts. First, there have been few improvements in the design of animal-drawn plows, carts, and other implements, or in the livestock breeds, for several centuries. Yet recent studies have shown that relatively simple design changes, such as more efficient harnesses and rubber-wheeled carts, can substantially improve the effectiveness with which animal power is transformed into useful work. And second, cattle dung is often burned for cooking fuel, a practice that deprives the soil of much needed fertilizer and reduces the efficiency of the forage-animal-crop energy cycle. If dung is fermented in a biogas plant, enabling the energy to be extracted and the nutrients to be returned to the soil, the economic contribution of animal power would be greatly enhanced.[51]

The growing energy-intensity of food production systems in both industrial and developing countries has been matched in the transportation sector. The energy used in transporting passengers and freight depends critically on the transportation system used. In most industrial countries, the least energy-efficient ways of moving people and goods have greatly increased their share of the traffic in the past few decades. And the energy efficiency of airplanes, automobiles, and trucks actually declined during the fifties and sixties.

Eric Hirst, an energy analyst from Oak Ridge National Laboratory, has calculated that the energy efficiency of aircraft dropped by nearly half between 1950 and 1970, as jet engines replaced more frugal piston engines. The efficiency of automobiles declined by about 12 percent over the same period, while that of trucks dropped marginally. Yet the airlines' share of freight and passenger markets in the United States rose by factors of 7 and 5 respectively in the fifties and sixties. The number of automobiles climbed from 40 million to 92 million, and trucks increased their share of freight transportation from 13 to 19 percent.[52]

Meanwhile, railroads were more than five times as energy-efficient in 1970 as they were in 1950, largely because diesel engines replaced steam locomotives. Yet the railroads lost freight business to trucks and airplanes; they accounted for 35 percent of the market in 1970 compared with 47 percent in 1950. Their share of passenger transportation dropped from 7 percent to 1 percent over the same period. Similar trends took place in urban transportation as automobiles, the least energy-efficient means of transportation, proliferated and as buses lost passengers.[53]

These shifts toward more energy-intensive transportation technologies have not been accidental. Jet aircraft offer advantages of speed, automobiles provide convenience, and trucks are more versatile than railroad cars. But government policies have also subsidized these less efficient systems through vast highway construction programs, airport building projects, and freight charges that have favored road transport over rail.

> **"Sales of bicycles in the United States have outnumbered those of cars since 1972."**

When transportation systems are constructed around the automobile, it is often difficult for other, more efficient technologies to compete. Such is the case with the bicycle in most cities. By far the most energy-efficient means of transportation, the bicycle plays a key role in many developing countries, but in the industrial world it has largely been pushed aside by the automobile. Many Third World cities are also becoming auto-centered. Recently, however, the bicycle has been staging a comeback.

Sales of bicycles in the United States have outnumbered those of cars since 1972; the number of bicycles in use in Japan climbed from 10 million in 1950 to 47 million in 1977, and they are now being produced at the rate of more than 6 million a year; and in Britain, yearly sales rose from 467,000 in 1970 to 1.2 million in 1975. One city that has made a major effort to accommodate bicycles in urban transportation plans is Davis, California, where an extensive network of bicycle paths has been constructed. A survey of traffic in Davis in the summer of 1977 found that bicycles represented 40 percent of all vehicles on one heavily traveled street. Urban planners in Dodoma, Tanzania adopted a similar philosophy: the master plan for the city decrees that the ratio of bicycles to cars will be 70:30.[54]

When oil cost $2 a barrel, energy efficiency was not a major preoccupation of transportation planners, but as its price rises, it will inevitably assume a more important role. For developing countries, the rising energy intensity of transportation systems built around automobiles and trucks should provide a warning of the costs involved in following in the footsteps of the industrial world. In the industrial countries, subsidies for energy-intensive transportation systems should be overhauled, and wider use of more efficient ways to move goods and people should be encouraged.

The availability of cheap and abundant fossil fuels has shaped technological developments in many areas other than agriculture and transportation. Advances in building technology, for example, have produced glass-walled, hermetically sealed structures whose chief concession to the external environment is found in the size of their heating and cooling systems. A study by the American Institute of Architects has indicated that improvements in the design of new buildings and modifications to existing ones could save a staggering 12.5 million barrels of oil a day by 1990. Thrifty building design includes adequate insulation, passive solar heating and cooling design, a minimum of lighting, and construction materials requiring less energy in their production, such as stainless steel rather than aluminum.[55]

The concept of planned obsolescence also matured in an era of cheap energy. The massive one-way flow of materials through most industrial economies, from mines to garbage dumps, requires vast amounts of energy at every stage of the journey. The extraction and processing of materials alone accounts for about 25 percent of all energy used in the United States, and most of it ends up on the trash heap. The average American generates about 1,300 pounds of solid waste a year, less than 7 percent of which is recycled.[56] Yet the production of steel from scrap requires only 14 percent of the energy needed to produce it from virgin ore; the equivalent figure for copper is 9 percent, and for aluminum, 5 percent.[57] Recycling can never be perfect, however. Reducing the materials consumed by industrial society requires designing products that are more durable and easier to repair, and eliminating wasteful packaging.

Finally, a less obvious source of inefficiency is the use of high-quality energy sources, such as electricity, to perform tasks where energy of a lower quality would be adequate. Electricity is a versatile energy source, capable of performing tasks ranging from the production of high temperatures to powering appliances and subway systems. But roughly three units of fossil fuels are required to generate one unit of electricity—the excess energy is usually rejected into the atmosphere as low-temperature heat. As physicist Amory Lovins notes, "This electricity can do more difficult kinds of work than can the original fuel, but unless this extra quality and versatility are used to advantage, this costly process of upgrading the fuel—and losing two-thirds of it—is all for naught."[58] Using electricity to heat homes and offices to 68°F is precisely the kind of application that does not make use of its quality and versatility.

As the world moves from an era of low-cost, abundant energy to an era when energy costs are bound to rise and oil and gas are expected to become scarce, the technological developments of the past provide neither sound models for the future nor a sound basis for the choice of energy technologies in developing countries.

Ecologically Sustainable Technologies

Two themes have dominated technological evolution for thousands of years: *wars, and the struggle by humanity to control nature.* In view of the formidable power of modern technology to manipulate biological systems for the production of food and fiber, to combat disease, and to provide protection from some of the vagaries of nature, it is sometimes tempting to conclude that one historic struggle is close to being resolved, at least in the industrial countries. But in the past few years it has become evident that ecological problems may constrain the use of some technologies.

The link between the introduction of a new technology and the gradual appearance of ecological problems is not new. Some 6,000 years ago, a civilization flourished on the floodplain of the Tigris and Euphrates Rivers, in what is now Iraq, as the development of irrigation technologies turned the desert into fertile land. Gradually, over the course of several centuries, however, the fields became a salty wasteland. Crop yields slowly declined, until production was no longer sufficient to sustain the civilization. The problem was caused by waterlogging of the subsoil and by the constant evaporation of irrigation waters, which left behind dissolved salts. The soil has not yet recovered, and in parts of southern Iraq the earth still glistens with encrusted salt. These particular irrigation technologies were not sustainable over the long term.[59]

The world is not on the verge of ecological collapse, but there is mounting evidence that many technologies being used today are not ecologically sustainable because of their long-term effects on people or on nature. One troubling possibility, for example, is that human activities may lead to irreversible changes in the earth's climate.

When it was first suggested a few years ago that the global climate may eventually show signs of human interference, the idea was greeted with due skepticism by many scientists. Recently, however, the skepticism has given way to concern. It is thought that carbon dioxide—an inevitable by-product of burning fossil fuels—is building up in the atmosphere and acting rather like a greenhouse, preventing a fraction of the earth's heat from being radiated into space. The ultimate result could be a rise in the average global temperature.[60]

The concentration of carbon dioxide in the atmosphere is already believed to have risen by about 13 percent since the Industrial Revolution, and it may double over the next 50 years. Such a change could increase average temperatures on the earth's surface by 2-3°C. The impact of a temperature shift of that magnitude is difficult to predict, but it is likely to affect agriculture in many regions. It could, for example, push the American corn belt northward onto less fertile soils. But it could also extend the growing season in the Soviet grain-producing region and draw monsoon rains into higher latitudes, which would benefit China's rice cultivation. In general, global warming would bring increased rainfall, and probably cause local weather patterns to become more variable.[61]

A more worrying possibility is that global warming could have an adverse impact on the stability of the polar ice caps. According to J. H. Mercer, in an article published in *Nature*, the anticipated doubling of carbon dioxide concentration over the next 50 years could raise polar temperatures by an amount sufficient to cause the West Antarctic ice sheet to break up. Such an event would raise the average sea level by about five meters, which would be catastrophic for many low-lying areas. As Mercer puts it: "If the present highly simplified climatic models are even approximately correct, this deglaciation may be part of the price that must be paid in order to buy enough time for industrial civilization to make the changeover from fossil fuels to other sources of energy. If so, major dislocations in coastal cities, and submergence of low-lying areas such as much of Florida and the Netherlands, lie ahead."[62] Some of Asia's principal rice-lands, such as the river floodplains in Bangladesh and Thailand, would also be inundated with salt water.

Although many uncertainties surround the predicted links between carbon dioxide in the atmosphere and global warming, the potential for serious and irreversible climate change provides an additional incentive to push ahead with a major program of energy conservation and development of renewable energy resources. Climatologist Stephen Schneider notes that if we wait until the carbon dioxide greenhouse theory has been proven correct by a warming of the atmosphere, it will be too late to take action. "Ten years of delay will put us ten years closer to potentially irreversible changes," Schneider warns.[63]

"The potential for serious climate change provides an incentive to push ahead with energy conservation."

While the carbon dioxide greenhouse effect may require major adjustments in energy policies and in long-term planning in many countries, another predicted link between technology and changes in the atmosphere has been easier to resolve. In 1974, researchers at the University of California suggested that fluorocarbon gases, which are widely used in aerosol spray cans, may damage the earth's protective ozone layer. Because the ozone layer helps block some ultraviolet radiation from reaching the earth's surface, it plays a critical role in shielding plants and animals from some of the damaging effects of the sun's rays. Among other things, certain kinds of ultraviolet radiation have been linked with skin cancer.[64]

Although the suggested links between fluorocarbons released from spray cans, damage to the ozone layer, and increased numbers of skin cancer victims are not accepted by all scientists, a string of committees, including one convened by the National Academy of Sciences, have reported that the matter warrants serious concern. Consequently, the use of fluorocarbons in spray cans is being phased out through government regulations in the United States and in some European countries. Unlike coal, fluorocarbons fortunately play only a peripheral role in the economies of the industrial countries, and their potential ecological threat has been easily dealt with.[65]

A more difficult ecological problem linked with the introduction of a new technology has arisen in some regions from overuse of pesticides. When DDT was introduced into agriculture in the late forties, it seemed like a miracle cure for a problem that had dogged farmers for centuries. The bollworm, which had decimated U.S. cotton fields, was brought under control in dramatic fashion, for example. But by the mid-fifties, worrisome problems began to emerge.

The budworm, an insect that had not previously been a major cotton pest, developed resistance to DDT and eventually to other pesticides as well. It subsequently assumed a leading role in the destruction of cotton crops in many regions. By the late sixties, farmers in the Rio Grande Valley were desperately spraying 35 times a year in attempts to control the budworm. Many cotton producers eventually went out of business. Similar problems developed in other countries where American techniques were adopted. Cotton farmers in Guatemala and Nicaragua, for example, have increased pesticide applications from 8 a year in the forties to about 40 a year in the mid-seventies. And overuse of pesticides in Peru's fertile Cañete Valley caused serious economic problems in the fifties as extra sprayings to control resistant pests reduced the farmers' incomes.[66]

Cotton is perhaps the most important U.S. crop to develop problems with resistant pests, for it now accounts for nearly half of all the pesticides used there. But it is by no means the only one. The onion maggot, a major pest of New York's onion crop, has developed resistance to a series of pesticides, and only one effective compound is left on the market. Soybeans in the United States are threatened by an insect that is beginning to acquire resistance to the only effective pesticide now in production. And out of 20 pesticides recommended for use in Michigan apple orchards in the past two decades, only 5 are still in use; resistance has developed to the other 15.[67]

In the future, pest control must turn to techniques that are ecologically more sustainable. Biological controls, such as the introduction of natural enemies of crop pests, the release of sterile male insects to reduce breeding, and the use of sex attractants to lure pests into traps are already being tried. Another effective strategy is crop rotation, which reduces losses from pests that survive in the soil during the winter.

Although some farmers are skeptical that such technologies will prevent major infestations, these methods are already widely used in some countries and their use is growing in the United States. A particularly striking example of ecologically sound pest management occurred in the Peruvian Cañete Valley after problems developed with conventional pesticides. In 1957, farmers in the valley organized an areawide control program that included the introduction of enemies of the cotton pests and more resistant cotton varieties, the rotation of crops, and the use of mineral insecticides only when necessary. Synthetic organic pesticides were banned. Production rose dramatically, almost doubling in seven years. A major incentive for farmers to turn to ecologically more sustainable techniques is the fact that overuse of pesticides has become economically unsustainable.[68]

The popular and scientific press abounds with examples of other technologies whose use may be ecologically unsustainable over the long term. Sometimes the problems show up fairly quickly. In a hydro-electric project at Anchicaya, Colombia, for example, the reservoir lost four-fifths of its capacity in just 15 years because of sedimentation, and salinity problems have appeared along the Colorado River as a growing number of irrigation projects return salty water to the river. More often, the ecological effects of a new technology take decades to become apparent.[69]

Such is the case with many carcinogens introduced into the environment, particularly in the workplace, through new technologies. The links between asbestos and lung cancer, vinyl chloride and liver cancer, and the drug diethylstilbestrol (DES) and vaginal cancer are but a few that have been definitively established many years after the introduction of each new compound. Each year, about 1,000 new chemical compounds are produced in the United States, yet until the passage in 1976 of the landmark Toxic Substances Control Act, there was no legal requirement that they be tested for long-term toxic effects.[70]

These are just a few examples of technologies whose impact on people or the environment may be unacceptable over the long term. In some cases, such as environmental pollution associated with specific technologies, new technology may alleviate the impacts. In other cases, such as the use of fluorocarbons in aerosol spray cans, the technology itself must be abandoned. Unlike civilizations in the past that have been confronted with potentially catastrophic ecological threats, humanity today at least has the ability to predict some dangers decades in advance. Whether that foresight will lead to corrective action is, however, another matter.

Technological Choices in Context

The relationship between technology and society is a two-way process. Technology has provided much of the driving force behind social change for thousands of years, and it underpins current economic and social systems. But social values, institutions, and political structures shape both the development and adoption of technologies. The pace of social change has quickened in the past few decades as the resources devoted to research and development have grown rapidly, and as institutions for disseminating new technologies have proliferated.

This vast infusion of technology into society has brought immense benefits. But it has not been without social and environmental costs. The four concerns discussed in this paper—rising unemployment, growing social inequities, dwindling oil and gas reserves, and potential long-term ecological problems—are all linked with technology. Some of the technological trends of the past few decades are not compatible with the social needs and resource constraints that lie ahead. Yet choices of technology made today by individuals, communities, corporations, and governments will have lasting impacts on the use of energy and resources. They will affect employment and income distribution for many years to come. Unless consideration of such impacts enters into judgements of which technologies should be developed and employed for particular tasks, some technological choices will lead to more problems than they solve.

Technological choices, whether in industrial or developing countries, are never made in a political or economic vacuum. The entire innovation process, from basic research to the introduction of a new technology, is conditioned by such factors as the profit motive, prestige, national defense needs, and social and economic policies. Those forces must be understood in any discussion of appropriate technology.

If technological development is to be more compatible with human needs, and more in harmony with the earth's resources, four principal points must be recognized. First, the unfettered workings of the market system cannot be relied upon to promote the development and adoption of appropriate technologies. Second, many technologies produced in the past few decades are becoming inappropriate in the industrial countries, and they are even less appropriate to the needs of developing countries. Third, the development of technologies that mesh with local needs and resources requires that developing countries be able to generate and apply new technologies, and it may also require new arrangements for sharing technologies within the Third World. Fourth, it must be accepted that technology, by itself, cannot solve political and social problems.

In most societies, market forces are the principal factor influencing the development and adoption of technologies. But they are at best an imperfect mechanism for ensuring that the development and introduction of new technologies will be socially and environmentally

"Technological choices, whether in industrial or developing countries, are never made in a political or economic vacuum."

acceptable. For one thing, the negative impacts of new technologies are seldom completely reflected in market prices. A few years ago, for example, some Canadian pulp and paper manufacturers routinely flushed mercury wastes down the drain, a process that was much "cheaper" than installing pollution-control equipment. The costs were borne by the people who ate contaminated fish rather than by the manufacturers or the users of pulp and paper products. Government regulations have since banned such socially irresponsible practices, and pollution-control equipment has been installed. Market prices now better reflect the true costs of the manufacturing process.[71]

Market processes can also work to perpetuate the use of inappropriate technologies. American automobile manufacturers find large, gasoline-guzzling automobiles more profitable to market than smaller, more energy-efficient cars, for example. In the absence of government regulation, Detroit would pay little heed to fuel efficiency, but federal regulations are forcing the automobile industry to shift its production gradually toward more efficient vehicles.

Governments have always strongly influenced trends in technological development, either directly through research and development and actual purchases of new technologies, or indirectly through subsidies, tax incentives, pricing policies, and support for such sectors as education, road building, health care, and so on. Nuclear power, for example, would not have been developed without immense government support; communications satellites owe their existence to a vast infrastructure of hardware and expertise that has been developed through national space programs; and transportation technologies require government assistance in the form of roads, airports, and docks. Governments therefore have great leverage in directing technological development along appropriate—or inappropriate—paths.

Most governments now accept some responsibility for ensuring that costs such as pollution and health hazards associated with some technologies are borne by the manufacturers and users of those technologies rather than by society at large. There is, however, need for more systematic methods for anticipating potential side effects of new technologies. The recent passage in the United States of the Toxic Substances Control Act, which requires preliminary testing of new chemical compounds for long-term toxicity, is a step in this direction. The Office of Technology Assessment, established as an agency of the U.S. Congress in 1973, has also published a number of studies highlighting potential long-term problems linked with new technologies. Such mechanisms can help to provide early warnings of side effects of technologies in time to take corrective action. But the development of appropriate technologies, as opposed to the control of inappropriate technologies, requires more direct intervention in market demands.

In the energy field, for example, government subsidies, direct purchases of equipment, and tax incentives could play an important role in promoting the development of renewable energy resources. Two serious impediments to the widespread use of solar equipment are the high immediate cost of the hardware to the consumer (despite its savings over the long run), and the lack of access to long-term credit facilities. Tax incentives, such as the recently adopted 55-percent income tax credit on all solar equipment in California, could play a significant role in stimulating the development of a solar heating industry, while a major government purchasing program could help bring down the cost of photovoltaic cells.[72]

The market system determines the price of goods and services in relation to current supply and demand. But it does not reflect the cost to future generations of the depletion of resources or of environmental degradation. Those costs can only be dealt with by effective conservation of the earth's resources through public policy.

In the developing countries, the market mechanism cannot work to stimulate the development and introduction of technologies that meet the needs of the poor, for the simple reason that the poor, by definition, are often outside the market system. Unless governments, foreign aid agencies, and community organizations assume responsibility for bringing appropriate technologies to subsistence farmers, small-scale manufacturers, and others now outside the market system, the poor may not benefit at all from technological progress.

Until recently, it has been tacitly assumed that Western-style industrial development would be the appropriate model for developing countries to follow. Just as similar technologies are now employed throughout the industrial countries, it was generally anticipated that

"Far from being a technological monoculture, the world of the future will have to be characterized by technological diversity."

the world would eventually be transformed into a sort of technological monoculture, with the same agricultural systems, transportation technologies, industrial processes, and building techniques used around the globe. But such assumptions were never valid.

The energy-intensity and materials requirements of many modern technologies make their use questionable not only in the developing countries but in the industrial world as well. Moreover, the costs—both in terms of capital requirements and social impacts of massive transfers of technology from rich to poor countries—would be prohibitive. Far from being a technological monoculture, the world of the future will have to be characterized by technological diversity if it is to be socially and ecologically sustainable. Each society will have to determine for itself what is appropriate in terms of its own needs and resources. No two societies are likely to need exactly the same mix of technologies.

The mechanisms for introducing technologies into developing countries—whether governments, corporations, or international agencies—all tend to promote a one-way flow from the industrial countries to the developing world. This is not surprising in view of the fact that virtually all the world's technological capacity is concentrated in the affluent nations of the North. But one result is that many technologies do not make effective use of either the physical or the human resources of developing countries. The technologies for making paper, for example, are based primarily on the use of softwoods that grow in cool climates; until recently, little attention was paid to the development of technologies that use cellulose materials abundant in the tropics. Similarly, until the past few years, small-scale energy technologies suitable for application in remote villages in the Third World received scant support from the world's technological powers, or from the elites in poor countries.

Aside from the fact that technologies developed in the industrial world may not mesh with the needs of the Third World—or indeed with the changing social and environmental conditions in the industrial countries themselves—the transfer of technology from rich to poor countries imposes a heavy financial burden. The developing countries are now paying about $10-20 billion a year directly and indirectly for imported technologies, and if present trends continue, those costs could soar to more than $150 billion by the turn of the century. Such projections assume, however, that developing countries will continue to buy many technologies that are inappropriate for their needs. Moreover, a group of development experts convened by the United Nations Conference on Trade and Development (UNCTAD) recently pointed out that "it will never be possible to build a world community based on genuine interdependence and capable of tackling global problems as long as three-fourths of that community is dependent on the other fourth for the ability to solve its own problems." The UNCTAD group went on to argue for greater technological self-reliance in the Third World.[73]

There is no easy formula for breaking the technological dependence of the developing world on the advanced industrial countries. But an important element in any such strategy is the strengthening of the capacity of developing countries to meet some of their own technological needs. This does not mean that the Third World should invest scarce resources in research and development institutes that simply copy those in the industrial countries. Rather, the need is to determine indigenous technological requirements and remove barriers to the development and introduction of technologies keyed to local needs and resources.

There is also scope for strengthening the technological links among developing countries. Because many countries face common problems that are not being dealt with adequately by the current technological world order, great potential exists for joint projects, information-sharing, and even transfer of technologies within the developing world. Indian scientists, for example, are now studying closely Chinese biogas plants to see whether they would be suitable for use in Indian villages. A new type of cement made from the ash of rice husks, recently developed in India, could be useful as a partial replacement for building cement in many developing countries. And sustainable, productive, dry-land farming techniques that have evolved in northern Nigeria may be relevant to the needs of farmers in arid zones elsewhere in Africa, Asia, and Latin America.[74]

It should be emphasized, however, that technological changes are only one influence on poverty, unemployment, and other pressing problems in the developing countries. Political, social, and economic transformations are also required to help raise the living standards of those who are now at subsistence level. Charles Weiss, science adviser to the World Bank, has noted that "evidence is piling up that the impact of the introduction of any particular piece of equipment—whether tractors in South Asia or waterless toilets in Viet Nam—*depends heavily on the social and institutional structures on which* it is superimposed. For this reason, there are many situations in which an intervention focused purely on technology—whether indigenous or foreign, new, adapted, or transferred—is likely to be doomed from the start."[75]

During the past decade, disenchantment with various aspects of the current technological world order has begun to manifest itself in various forms. Developing countries have argued strongly for a restructuring of the global economic system, and their frustrations with the technological dominance of the industrial nations lie behind the plans for a United Nations Conference on Science and Technology for Development scheduled to take place in August 1979 in Vienna. And in the industrial countries, the rise of the environmental movement, the emergence of the technology assessment movement, and the formation of appropriate technology groups signify a measure of disaffection with some aspects of modern technology.

It is relatively easy to identify some of the key criteria for determining whether a technology is appropriate, but far more difficult to devise the social mechanisms to ensure that appropriate technologies are developed and applied. It is also difficult to generalize from one society to another. Only by paying careful attention to the impact of new technologies on people, social systems, and the natural environment will the picture of an appropriate technology for any particular situation begin to emerge. There are, however, no technological panaceas. Only hard choices.

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