# Green Technologies for Development

*Transfer, Trade and Cooperation*

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# Green Technologies for Development

## *Transfer, Trade and Cooperation*

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# Preface

## *Poverty, environment, and technology*

The debates leading up to the United Nations Conference on Environment and Development (UNCED) have given new life to the subject of North-South technology transfer. Once at centre stage in development debates, by the mid-1980s technology transfer had been shunted aside and replaced by concerns over debt, macroeconomic adjustment, trade liberalization, and — more recently — sustainable development. Yet, as awareness has dawned that efforts to involve developing countries in environmental action must provide them with the financial and technical resources to achieve desired environmental goals, a variety of actors in both North and South have begun to re-examine the technology issue.

To a large extent, unfortunately, this re-examination has been narrowly defined, focusing on the "supply side", and in particular on the financial, institutional, and legal mechanisms by which technologies currently applied in the North can be transferred to developing countries. As a result, a whole range of "demand side" questions have been downplayed, particularly those related to the nature of developing country technology needs, the role of developing country research systems, and the factors affecting the adoption of technology. This report attempts to provide a somewhat wider perspective, by looking at the role of technology in combatting environmental degradation and the potential of international cooperation in fostering this role.

The starting point for the report is a recognition of the linkages between poverty, population, and sustainable development. As Sridath Ramphal has remarked, in developing countries, poverty, rapid population growth, and environmental degradation are closely interrelated, through feedback cycles absent in richer societies:

> Poor people often destroy their own environment — not because they are ignorant, but to survive. They over-exploit thin soils, overgraze fragile grass lands, and cut down dwindling forest stocks for fire wood. In the context of short term needs of survival each decision is rational; in the longer term and wider context, the effects are disastrous ... Poverty is both a cause and an effect of environmental degradation (Ramphal, 1990, 39).

This is not to suggest that the blame for environmental degradation should fall on the poor. Misguided development paths and the rates and patterns of consumption in the industrialized countries bear far more responsibility for current damages and threats. Any concern for intergenerational equity cannot be ethically or practically maintained without a simultaneous pursuit of equity in the present. Efforts by the world community to tackle current environmental threats must simultaneously confront the realities of poverty and the vast disparities in resources and opportunities within and among nations.

What role can technology play in a poverty-focused approach to environmental protection? Technology — understood here as the mix of knowledge, organizations, procedures, machinery, equipment, and human skills that are combined to produce socially desired products — is not simply a tool of social engineering. Economic and social structures shape the definition of social problems and hence the directions of technological change: in turn, changing technologies reshape social and production organizations. As such, there is need for considerable skepticism about the role of technology in overcoming problems that are, at their roots, social and political — and about the ease with which technological solutions developed in one socioeconomic context can be transferred to another.

In both North and South, there is a growing awareness that technology does not on its own provide the answers to the challenge of development. Convenient assumptions linking technological advance with increased productivity and improvements in living standards are challenged by the realities of vast disparities in income and wealth between rich and poor, by the enclave nature of much industrial production, and by problems of indebtedness and capital flight. The link between technology and **sustainable** development is even more suspect, eroded by public perception of the disastrous environmental impacts of past industrial development and the ways in which presumably "benign" technologies — chlorofluorocarbons, for example — have in practice had unforeseen and damaging effects on the biosphere. More generally, it is now recognized that the environment is more than a set of biophysical indicators: attention must be directed to the human dimensions of environmental degradation, incorporating insights from the social as well as the natural sciences.

Nonetheless, any strategy to promote more sustainable patterns of development must draw upon technology. Environmental damage need not be an inevitable consequence of industrialization, technological advance and economic growth. New technologies already available provide a wide range of solutions to the recognized problems of the environment, and potential future technologies hold out the prospect of even more radical changes. What has until now been lacking is 1) an international agreement that the local and global environments need to be protected and sustained, and 2) a commitment to pursue the host of social, legal, and economic reforms needed to enable economic development, environmental protection, and technological change to work toward this end.

Changes are beginning, however. Many developing countries now recognize the urgency of international efforts to address global environmental threats — although they remain concerned about possible conflicts between environmental and developmental goals, about the overwhelming emphasis on global as opposed to local environmental issues, and about the ways in which the burdens of environmental adjustment will be shared between North and South. In the North, meanwhile, global environmental threats have provided a renewed and compelling illustration of the mutual interests of industrialized and developing countries and of the necessity of international cooperation. Images of rain forest destruction, the extinction of species, or the threat of climatic disruptions, have been the symbols around which a global environmental constituency has coalesced.

There is hope for international action in the application of science and technology to environmental concerns — a hope born of the urgency of current environmental problems, of the new-found recognition of mutual environmental interests between North and South, and of the fundamental role of science and technology in assessing and responding to environmental threats. To the extent that this does indeed come to pass, it may also offer a possibility to revisit some of the old but as yet unresolved issues regarding North-South technology transfer and the international economic order more generally.

# The Environment, Then and Now

## *The current agenda*

As early as 1968, Paul Ehrlich argued that in many countries, the population had outgrown the environment's capacity to grow enough food. Famine on a large scale was imminent, he warned. Similarly, the Club of Rome's influential *The Limits to Growth,* claimed that the rapidly growing world population was consuming nonrenewable resources at an alarming rate, and that critical shortages loomed in the near future.

The dire warnings of Ehrlich and the Club of Rome receded in importance as the Green Revolution increased food production. Advancements in geophysics and the continual search for new resources have expanded known resource availability ten-fold. New technologies combined with changing consumption patterns and improved efficiency have to a great extent alleviated fears of resource depletion.

During the same period, however, other alarms were sounded. As early as 1962, Rachel Carson's *Silent Spring* pointed to the human and animal health dangers caused by DDT and other chemicals. The threats highlighted by Carson have grown in importance as a result of the increased use and variety of chemical pollutants. The current environmental "crisis" is not a result of scarcity and shortages, but instead of the increased scale and variety of production activities.

Today's environmental problems are characterized by four distinct features:

- An important change in scale, with a shift from relatively small quantities of pollutants to increasingly large quantities. Many of the pollutants of concern (carbon dioxide, methane) have existed for a long time, but now overwhelm the capacity of natural cycles to deal with them. In addition, the rapid acceleration of pollution and resource degradation has raised new concerns regarding erosion of agricultural soils, loss of forests, overuse and pollution of fresh water, and loss of species.
- An almost exponential growth in the number and diversity of impacts as a result of the increasing shift from naturally occurring pollutants to synthetic ones. Today, there are over 80,000 chemicals in use, with scores of new chemicals added each year.

- Environmental threats do not respect national boundaries, but instead are often transboundary or global in their effects. The whole world suffers from the pollutants of the North's prolific factories. Developing countries are important contributors to some environmental problems and will become even more important as their populations expand and industrialization spreads.
- The various environmental threats are inextricably linked, both in their causes and their effects. As a result, individual environmental problems cannot be studied or acted upon in isolation.

The growing debate and crisis surrounding questions on the environment have exposed a significant North–South rift, which has risen repeatedly in recent years. It is instructive to separate the issues currently on the table into "global" and "local" issues.

For its part, the North has focused its attention on "global" issues such as ozone depletion, greenhouse warming, tropical deforestation, and the erosion of biodiversity because their far-reaching effects have mobilized public attention and political action in the North.

## *Ozone depletion*

Ozone depletion is not only of interest as an area of Northern attention, but also as a model for action. Reaction to the accumulation of gases in the atmosphere containing chlorofluorocarbons (CFCs) has been relatively swift and has become a standard against which other negotiations are now judged. Early scientific evidence regarding CFCs led the United States to ban the nonessential use of CFCs as an aerosol propellant. This was followed by international negotiations leading to the Vienna Convention (1985), the Montreal Protocol (1987), and most recently, amendments to the Protocol in Helsinki (1989) and London (1990). Within a period of five years, the international community agreed to ban the future production and use of CFCs over a specified time period.

Even so, recent observations of atmospheric ozone suggest that due to the overhang of CFCs already present, destruction of the ozone is likely to be more serious than anticipated earlier. This (combined with the relative ease of substituting alternative technologies) has led many countries to advance timetables for eliminating CFCs. In March 1992, for example, Canadian federal and provincial environment ministers advanced the deadlines for eliminating man-made chemicals that are destroying the ozone layer. It was decided that the production and import of CFCs will be phased out by the end of 1994, one year earlier than previously announced. Halons, which also destroy the ozone layer, will be phased out by the end of 1994 instead of the year 2000. The provinces will have mandatory programs to recover and recycle CFCs by the end of 1992. This marks the second time in two years that Canada has accelerated its deadlines for eliminating products which destroy the ozone layer.

## *The greenhouse effect*

Climate change and the presence of greenhouse gases in the atmosphere have captured headlines. Climate change has become the dominant symbol of global environmental problems, and the prime mover of international environmental diplomacy.

While many uncertainties about climate change remain, the report of the scientists forming the Intergovernmental Panel on Climate Change (IPCC, 1990) established that

- emissions resulting from human activities are substantially increasing the global atmospheric concentration of so-called greenhouse gases: carbon dioxide ($CO_2$), CFCs, methane, and nitrous oxide;
- these gases magnify the natural greenhouse effect; and
- the enhanced greenhouse effect will increase warming of the earth's surface, which in turn will increase the formation of water vapour, thus enhancing the warming trend.

The IPCC predicts these trends will cause average global warming of approximately one degree Celsius in the next 35 years and three degrees in the next 100 years. Not since the last ice age, 10,000 years ago, has the world experienced such temperature fluctuations. This could cause global sea levels to rise 20 cm in the next 35 years and 65 cm over 100 years. Low-lying countries such as the Netherlands and Bangladesh could be devastated by such rises. Rising global sea levels could also result in migration, extinction of species, significant alterations in rainfall patterns, and substantial disruption of agriculture and forestry.

## *Forests and deforestation*

The issue of climate change is closely linked to the world's forests. Concern for tropical forests has increased because of $CO_2$ emissions produced by "slash and burn" techniques of deforestation, and because of the ability of forests to act as "carbon sinks" that lock up $CO_2$ produced by other activities. Any attempt to deal with climate change will have to address the use of global forest resources and provide guidelines for both afforestation and reforestation.

The role of forests beyond global warming is also being recognized. Forests are important as repositories of biological diversity, sources of productive employment, and contributors to water management and erosion control. The Rio Summit made some progress in this direction, with the adoption of a non-binding statement of principles on the management, conservation and sustainable development of all types of forests.

## *Biodiversity*

The rapid loss of plant and animal species has emerged as a compelling illustration of the global costs of environmental degradation. North and South are beginning to realize the importance of preventing the erosion of the planet's genetic diversity. Agriculture and medicine depend greatly on genetic material which originates largely in the South. This awareness has been spurred in part by growing doubts about the effectiveness of Northern gene banks and the need to preserve native species.

Developing countries insist that any discussion on biodiversity must also touch on issues of direct economic significance to them. In practice, this has lead to discussions on two issues:

- A demand — now gaining international acceptance — for a system of "farmers' rights" that would compensate developing-country producers of the genetic material on which improved varieties are based; and
- A much more contentious demand that developing countries be guaranteed preferential access to the outputs of biotechnology research in the North as compensation for Northern access to Southern biological resources. This latter demand has now been enshrined in the Convention on Biological Diversity negotiated at the Rio Summit. The United States' objection to the clause — and refusal to sign the convention — resulted in the most heated dispute at the Summit.

## *Local issues*

Public debate in the North has been dominated by the preceding global issues, but it is crucial to remember that these are not the only issues of significance. Local issues such as desertification, marine pollution, hazardous wastes, solid waste management, and the urban environment have immense impact and importance in the South, but receive little international attention.

In some cases (marine pollution), these issues have significant transboundary impact; but, in most cases, their impact is more localized and is felt overwhelmingly in developing countries. Nonetheless, the combined significance of these "local" phenomena is as great as the so-called "global" issues. They have received comparatively little public attention to date — either because they do not directly affect industrialized countries (desertification) or because industrialized countries have already taken action to deal with them, however imperfectly (hazardous wastes, solid waste management, urban environment).

For most developing countries, such local problems are at the core of their environmental priorities. Southern countries admit the importance of global environmental threats, but they argue with considerable justification that these threats have resulted largely from the effects of pollution and overconsumption in the North, and that the North should thus bear the brunt of the costs of dealing with such problems. According to this view, the debates to date have had two particularly perverse consequences. First, attention has centred on the potential future contribution of Southern countries to global issues such as climate change or biodiversity, stressing projected rates of loss of tropical forest cover, or the potential growth of energy demand in developing countries. The current contribution of Northern countries is downplayed, as is the scope for immediate improvements as a result of unilateral action by the North. Second, concern for global issues has deflected attention from consideration of the equally serious local problems affecting developing countries.

Such issues, the developing countries maintain, are the key to the environment–development linkage. Concern for global environmental improvement has overshadowed the need to address the problems of underdevelopment and poverty that are at the root of the South's environmental agenda. Issues of poverty, population growth, and employment are, in this sense, central to global environmental debates.

But attention in the North remains fixed on global issues, and on the environment rather than development. In the realm of technology, the bulk of scientific research and funding for technology transfer is directed at global issues. As a result, there is a significant danger that local issues will not receive the scientific consideration and technology they deserve.

Yet, any comprehensive attempt to mobilize international scientific and technological resources must deal with these issues. The North needs to broaden its perspective to realize it also has a stake in promoting more sustainable patterns of development worldwide. Issues such as sustainable agricultural production or urban environmental problems should be every bit as much a "global" concern as ozone depletion and climate change.

## *Need for international action*

Even a cursory review of this environmental agenda illustrates the pressing need for international action. At the very least, the following conclusions can be drawn.

**First**, the scope of current environmental threats, and their inherently transboundary or international impact, means that any effective strategy to tackle them must involve cooperative efforts by North and South.

**Second**, although uncertainties remain, they are not sufficient to warrant postponing action. There are, of course, significant areas in which current scientific knowledge is deficient. But time alone will not make the problems go away, and in the absence of significant efforts at an early stage, both the scale of impacts and the demands of any amelioration program are likely to be much larger. With this in mind, the Rio Declaration calls on the international community to apply the "precautionary principle": "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation".

**Third**, there are significant asymmetries between North and South that must be taken into account. The imbalance in **responsibility** for current threats is clear: although the potential future contribution of developing countries to global warming and other threats is startling, the inescapable fact remains that historically the bulk of environmental degradation has resulted from activities undertaken by industrialized countries. Similarly, the imbalance in **resources** between North and South — technical, financial, managerial, and institutional — is undeniable. And in part because of the imbalance in scientific and technical resources, the state of our knowledge regarding environmental threats is asymmetric, with important gaps in our knowledge as to the causes and consequences of environmental degradation in developing countries. As a result of all these factors, industrialized countries will have to take the lead in responding to current environmental threats, both by action to reduce their own contributions and by international cooperation to assist developing countries.

**Finally,** any strategy to deal with current environmental problems must address the issue of science and technology. Although technology is by no means a panacea to environmental degradation, scientific and technological capabilities are essential to the diagnosis of environmental threats and to the design of strategies to counter these threats. Yet, it is precisely in this area that the disparity between North and South is most daunting. Given this disparity, efforts must be made to transfer relevant technologies from industrialized countries to developing countries and to strengthen the capabilities of developing countries to select,

## *Unequal Uncertainties: The Methane Debate*

Debates about combatting global climate change place considerable weight on reducing emissions of methane. Like carbon dioxide, methane concentration in the earth's atmosphere is increasing rapidly by nearly one percent per year. However, unlike carbon dioxide, methane has a relatively short-lived impact. Its atmospheric lifetime is approximately 10 years, compared to 100 years or more for other greenhouse gases. This short lifetime makes methane relatively easy to control and makes reducing its emission economically efficient when compared to other greenhouse gases.

On the other hand, there is considerable uncertainty about the actual contribution of methane to global warming — alongside doubts about how data on methane figures is being used and reported. Methane is produced in three principal ways: stomach gas from livestock; fermentation in irrigated rice fields; and leakages from coal mining, oil and gas exploration and transportation, urban landfills and sewage plants. While the latter source accounts for some 40% of total methane emissions, much is made of the first two sources, where the contribution of developing countries is relatively large. As Agarwal and Narain (1991) note, however, estimates of methane production from livestock and paddies are open to a wide margin of error and are based on extremely sketchy data. When atmospheric sinks for methane are figured in, total excess production of methane may in fact be quite small.

This knowledge suggests the need for considerable skepticism about the contribution of methane to global climate change. More broadly, it underlines the extreme asymmetry between North and South in terms of understanding the factors contributing to climate change: while our knowledge of Northern CFC and $CO_2$ production is relatively well-advanced, knowledge about Southern contributions, including methane, are much less certain. Such an asymmetry reinforces the importance of increasing scientific capability in developing countries to permit their effective participation in debates about global environmental threats.

adapt, and create the technology necessary to deal with environmental threats.

## *Lessons of previous international negotiations*

Several previous sets of international negotiations have attempted to broach the contentious subject of North-South technology transfer, with varying degrees of success. Ongoing negotiations on a proposed international code of conduct on transfer of technology have been carried out since 1972 under the auspices of the United Nations Conference on Trade and Development (UNCTAD). The 1982 Law of the Sea Convention also contains several provisions on the transfer of technology to developing countries. More specifically, in the area of environmentally sound technologies, there are three international agreements of relevance: the 1979 Long-Range Transboundary Air Pollution (LRTAP) Convention dealing with acid precipitation in Europe; the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer; and the 1989 Basel Convention on the Transboundary Movements of Hazardous Wastes and their Disposal.

At best, however, such international negotiations provided a partial model for the debates on technology transfer at UNCED, and for the type of action required in the years ahead.

The closest parallel, of course, is the Montreal Protocol, and there has been considerable optimism that these negotiations have yielded a new model for future international environmental diplomacy (Benedick, 1989).

The Montreal Protocol (and particuarly the 1990 London Agreement revising the Protocol) introduced unprecedented language regarding the transfer of technology. First, it included a strongly worded obligation on signatories to take all possible steps to transfer the "best available" technologies on fair and favourable terms to developing country parties. Second, it provided for the creation of a multilateral fund to finance the incremental cost to developing countries of compliance with the terms of the Convention. And, third, it stated clearly that the ability of developing countries to fulfil their obligations under the Convention was dependent upon the implementation of the provisions regarding financial cooperation and technology transfer.

There is little doubt that the Montreal Protocol experience formed at least an implicit backdrop to the negotiations in Rio, and will continue to do so in future environmental debates. The type of agreements reached in the ozone accord on technology transfer and financial cooperation have set a benchmark against which developing country participants will now judge subsequent agreements in other fields. The Montreal Protocol experience also demonstrates the utility of a flexible, incremental approach to negotiations, in which an initial agreement is quickly established in international law, but in which the treaty is deliberately designed to be reopened and adjusted as needed, on the basis of periodically scheduled scientific, economic, environmental, and technological assessments. The signing of a framework convention in Rio suggests that the climate change negotiations may well follow a similar pattern.

At the same time, there are several factors that limit the relevance of the Montreal Protocol as a model for future debates. In the first place, the success of the Montreal Protocol was due in large measure to the degree of scientific consensus over the causes and likely effects of the depletion of stratospheric ozone. The lack of scientific consensus on other issues (notably climate change) has worked against efforts to reach a speedy agreement between North and South.

Second, and equally crucially, the Montreal Protocol succeeded in large part because of the limited nature of the problem under consideration, the limited range of alternative technologies to replace CFCs, and the resultant ability to predict and limit the financial obligations resulting from the treaty. In the case of climate change and other environmental issues, the sheer scope of the problems and the uncertainty regarding costs may stall attempts to reach binding, comprehensive agreements on issues of financial and technological cooperation.

The Montreal Protocol experience also illustrates the long-term nature of action to promote international transfer of technology. Even under the most favourable conditions, negotiating international agreements is a lengthy, time-consuming process — as is the implementation process. Pressures for speedy action have been strongest in the case of the Montreal Protocol, but even in this case action has been somewhat slower than expected. The Multilateral Fund provided for in the Protocol has now been established under the joint auspices of the United Nations Development Program (UNDP), the United Nations Environment Program (UNEP), and the World Bank. But contributions from sponsoring nations have been slow in materializing, and this — combined with the mundane process of appointing staff, organizing day-to-day operations, and formulating selection criteria — has meant that project disbursements have been far slower than expected.

## *A blueprint for the next century*

The round of international negotiations which took place at UNCED, was further proof of the increasing global concern over the links between environment and development.

Not surprisingly, opinions on the success of UNCED have been mixed. On the one hand, considerable progress was made on a variety of fronts, ranging from the Rio Declaration on the Environment and Development, to the Convention on Biological Diversity. In addition, the Summit served as the forum for the announcement of a number of national and regional initiatives. Canada, for example, announced that IDRC's mandate would be broadened to become an "Agenda 21" organization, in support of sustainable and equitable development.

On the other hand, progress fell far short of some of the more optimistic expectations. Negotiations on climate change and on forests fell short of full conventions, while the success in negotiating the biodiversity convention was marred by the refusal of the United States to sign the convention. And while significant pledges of new financial resources were made (notably from the Japanese), these fell far short of even the most conservative estimates of the amounts needed to implement Agenda 21.

The best long-term measure of the success of the Earth Summit will be the extent to which it galvanizes action at the national and international level. In this light, it is best to view the Summit as one of a number of steps toward desired goals, rather than as the final forum for achieving those goals. Progress was made, but few if any of the issues facing the Summit were resolved in their entirety at Rio. This is certainly true in the area of technology transfer, where the kinds of agreements reached at Rio will need to be followed with ongoing initiatives by a variety of actors.

The South's approach to UNCED was quite receptive considering fears of environmental conditionality and protectionism. At the 1972 Stockholm Conference, the South took a negative stance towards calls for action on environmental concerns. Developing countries viewed these as additional barriers to development thrust upon them by a developed world that, having prospered as a result of profligate resource use, was now asking the South to forego such benefits in the interests of a cleaner planet.

The change in attitude is due to the mounting evidence that certain aspects of global environmental change — e.g., rising sea levels because of climate change — will affect some developing countries more seriously than their Northern counterparts. It also reflects a growing sense that the increasing political weight of the environmental movement in the North has made the environment "card" the strongest one in a generally weak Southern "hand", and one that must be played skillfully if the South is to link environmental concerns with its own development priorities.

In the North, meanwhile, the prospects for action have been raised by a variety of factors: the increasing recognition that environmental protection and enhanced competitiveness may be complementary rather than contradictory goals; the growing strength of the domestic environmental movement, which has moved to the mainstream of political opinion; and the realization that the global nature of environmental threats makes defensive, "not in my backyard" responses untenable.

Technology transfer emerged as one of the most contentious issues in the lead-up to UNCED. Even though both the North and the South accepted the need for some form of action to facilitate the transfer of environmentally sound technologies, there was still a wide gap between the two positions.

**Northern** countries tended to stress the following four points:

- The need to ensure adequate financial compensation to inventors via developing-country recognition of intellectual property rights;
- A conviction that, as far as possible, technology should be provided on nonconcessional (commercial) terms, with no across-the-board guarantee of concessional access;
- A desire to limit the range of technologies under consideration, in particular by separating the climate change convention from other issues under discussion at the Summit; and
- A preference for working through existing institutions to channel funds to support technology transfer activities, particularly the Global Environmental Facility (GEF).

However, within the Northern "camp" there are some important differences of opinion. The United States has tended to take the hardest line in terms of intellectual property rights and nonconcessional access. Other countries, notably Japan and Germany, have taken a softer line. This reflects their leading positions as suppliers of environmentally sound products, and the related perception that the principal economic benefits lie not in protecting rents associated with patents, but rather in aggressively promoting emerging environmental industries.

The **Southern** position, conversely, has tended to stress the following points:

- The need to secure access to the latest available technology, including proprietary technology, without conditionality in terms of reform of Southern patent legislation;
- The importance of concessional transfers, with the North bearing most of the costs of providing the relevant technologies;
- The need to consider the entire range of environmentally sound technologies, not just those related to global warming; and
- The importance of channelling funding through new institutions that would ensure an adequate voice for the developing countries in their constitution and operation.

The Southern position also emphasized the need to negotiate a trade-off between Northern access to Southern plant varieties and Southern access to the results of biotechnology research being carried out in the North.

To a large degree, discussions on the transfer of "environmentally sound" technology tended to mirror earlier debates about North–South technology transfer, both in the gulf separating the Northern and Southern positions and in the nature of the issues addressed. As Martin Bell has pointed out with respect to the climate change negotiations, much of the debate centred on the broad legal, institutional and financial arrangements governing developing country access to technologies developed in the industrialized world (Bell, 1990).

As a result, a whole range of questions were downplayed or ignored: these included questions related to the nature of developing-country technology needs, the generation of more appropriate technologies to meet those needs, the expertise needed to ensure effective transfer, and the factors affecting adoption, assimilation, and adaptation of imported technology.

At the same time, there were some signs of a movement away from this situation, and even of partial consensus between North and South. In particular, there was a growing recognition in both North and South that any effective strategy must involve not only the transfer of technologies from North to South but also the strengthening of indigenous Southern technological capabilities, through a variety of training and capacity building measures. At the same time, some developing countries worried that industrialized country support for capacity building and "technology cooperation" might serve to detract attention from the crucial issues of financing and concessionality.

In the end, issues of technology transfer and development figured in various aspects of the UNCED debates.

To begin with, the Rio Declaration on the Environment and Development stresses the need to "strengthen endogenous capacity-building for sustainable development by improving scientific understanding through exchanges of scientific and technological knowledge, and by enhancing the development, adaptation, diffusion and transfer of technologies, including new and innovative technologies".

## *Technology and Agenda 21*

More specifically, the Agenda 21 document agreed to in Rio includes a chapter on "Transfer of Environmentally Sound Technology, Cooperation and Capacity-Building". Issues of relevance to technology transfer are also broached in the chapters on"Science and Sustainable Development" and on "Environmentally Sound Management of Biotechnology".

The technology transfer chapter outlines five broad objectives for the post-UNCED period:

- to help ensure access by developing countries to scientific and technological information, including information on state-of-the-art technologies;
- to promote access to, and transfer, of environmentally sound technologies;
- to facilitate the maintenance and promotion of environmentally sound indigenous technologies;
- to support national capacity-building, particularly in the South, so that developing countries can assess, adopt, manage and apply environmentally sound technologies; and,
- to promote long-term technological partnerships between holders of environmentally sound technologies and potential users.

It outlines a number of specific steps which could be undertaken to further these goals, ranging from improved information systems to the purchase of patents for transfer to developing countries. The average annual cost of these activities to the year 2000 is estimated at between $450 million and $600 million, excluding non-concessional resources.

The final Agenda 21 document is a significant advance over earlier versions, and illustrates the substantial evolution in thinking on technology transfer which occurred during the lead-up to UNCED. In particular, the document strongly asserts that efforts to facilitate the North-South flow of technologies must be accompanied by attention to human resource development and local capacity building. It also stresses the importance of indigenous technological knowledge, and the need for long-term cooperation between technology suppliers and recipients.

At the same time, there are severe limitations to the document. The document calls on states to "promote, facilitate and finance" the transfer of environmentally sound technologies and related know-how "on favourable terms, including on concessional and preferential terms". Not surprisingly, however, no specific institutional or financial mechanism to support such an objective is proposed, nor are any timetables for action put forward. Similarly, there is no indication of how financial resources would be raised or distributed.

While the technology transfer provisions in Agenda 21 include important statement of principles and useful catalogues of potential actions, they fall short of providing an "action plan" for the coming years. As with other parts of Agenda 21, the difficult work of deciding among conflicting priorities, designing specific programs, and setting in motion the institutional machinery to manage them, all lie ahead.

## *The Conventions*

Some of the same achievements and limitations are evident in the progress made at Rio on the technology transfer provisions of climate change, biodiversity and forests conventions.

In each case, some attention was given to technology transfer. Even the statement of principles on forests echoes the Agenda 21 document in stressing the importance of efforts to promote, facilitate and finance the transfer of environmentally sound technologies "on favourable terms".

The framework convention on climate change expressly commits the parties to "promote and cooperate in the development, application and diffusion, including transfer, of technologies, practices and process that control, reduce or prevent anthropogenic emissions of greenhouse gases" (Article 4). To a large extent, the Convention follows the example of the Montreal Protocol. It states that the ability of developing countries to implement the provisions of the Convention will be dependent upon the commitments by developed country parties to provide financial resources and transfer of technology. It also commits the developed country parties to provide financial resources to cover the "full incremental costs" to developing countries of implementation of the Convention.

At the same time, the document falls short of the provisions of the Montreal Protocol in at least one respect. It makes no mention of the terms upon which technology would be transferred, other than a statement in the preamble that new technologies should be transferred "on terms which make such an application economically and socially beneficial".

The Convention on Biological Diversity is more explicit in this regard, stating that techologies relevant to the conservation and sustainable use of genetic resources "shall be provided and/or facilitated under fair and most favourable terms, including on concessional and preferential terms where mutually agreed". At the same time, it states that transfer of patent-protected technology will be "consistent with the adequate and effective protection of intellectual property rights".

The most contentious issue in the Convention, however, is its provision for the sharing of the results of biotechnology research. The Convention commits industrialized country parties to provide developing country parties with access to technology which makes use of genetic resources provided by that developing country. This applies even in cases of technology protected by patents or other intellectual property. The Convention similarly calls on industrialized countries to "provide for effective participation in biotechnological research" by developing countries which provide the genetic resources for such research. It was these provisions regarding access to biotechnology research which prompted the much-publicized refusal of the United States to sign the Convention in Rio.

## *The road from Rio*

With regard to the conventions as well as Agenda 21 itself, agreements reached at Rio represent a first step on a long and arduous journey.

In the area of technology transfer, there is a need to move from basic principles and calls to action to more concrete plans and strategies. At the same time, however, it is essential that future action be based on a close and careful assessment of the issues at hand.

The next section of this report attempts to do just this, reviewing some of the conceptual issues in the transfer and development of environmentally sound technologies, and the lessons of past research on North–South technology transfer. In the final session we return once again to strategies for action in the post-UNCED period.

# Technology, Environment and Development

## *Environmentally sound technologies*

Discussing the application of technology to global environmental problems must begin by examining the nature of technology needs. Narrowly defined, "green" or "clean" technologies are those required to modify or improve specific products and processes that cause environmental damage. This definition was adopted by the Montreal Protocol in relation to ozone-depleting substances. Many observers, particularly in the South, want a broader definition that includes the transfer of all "environmentally sound" technologies. But there is considerable confusion about the meaning of this term.

When assessing environmentally sound technologies, three points should be considered. First, there are a number of criteria for environmental soundness. In practice, few technologies will meet every criteria while some will solve one problem only to create another. Second, environmental soundness is a relative concept. At any given time, a particular technology may be environmentally sound; however, at a later date, new and more environmentally sound technologies are likely to emerge. Moreover, a technology initially considered environmentally sound may turn out to be unsound (e.g. CFCs) once increased knowledge of long-term effects is known. Third, environmental soundness often depends upon the specific site of its application, the mix of environmental and economic criteria to be met, and the general conditions in which a technology operates.

## *Defining environmentally sound technologies*

While it is difficult to define precisely what constitutes "environmentally sound" technologies, it is possible to identify some general characteristics, provided there is agreement on the major environmental threats facing us. Further, to the extent that environmental degradation is a result of poverty, environmentally sound technologies must increase wealth-creation and employment opportunities in the South. In general terms, the technologies needed for a transition to more sustainable development would have to address the following goals:

- increased rates of economic growth and expanded employment opportunities in developing countries, coupled with greater sensitivity to the resource endowments of these countries.
- increased efficiency in the use of raw materials and energy.
- elimination or reduction of the amounts of harmful wastes generated in production and, where such wastes are produced, ensuring minimum hazards to human health.
- promoting the reuse or recycling of inputs and final products.

It is not possible at this point, however, to meet the demand of the North to identify a set of environmentally sound technologies and limit concessionary financing to that set of technologies. There is no rational basis by which such a set can be predefined. The makeup of such a set would have to evolve over time through assessing and applying various technologies in terms of their potential to remedy a particular problem and the likelihood they will not create other environmental problems.

It is apparent that the range of potentially environmentally sound technologies is extremely broad. By looking at the problem of climate change, for example, environmentally sound technologies might include the following:

- **Technologies to limit the use of CFCs.** These technologies are already targeted for transfer under the Montreal Protocol. They include technologies to manufacture CFC substitutes such as hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs); new processes to replace CFCs; technologies for substitute products (e.g. refrigerators without CFCs) as well the process technologies needed to use the new product; and technologies to recycle CFCs in existing appliances such as air conditioners and refrigerators.
- **Technologies that reduce the amount of primary energy required for a given use.** Increasing energy efficiency in end use provides the most immediate potential to slow the growth of $CO_2$ emissions. Approximately one-third of the $CO_2$ produced in the industrialized countries (and more in the developing countries) is generated by electricity production. More efficient domestic appliances, residential and commercial heating systems, and industrial electric motors would reduce the need for energy.
- **Technologies to improve the efficiency of energy production.** As developing countries create additional power generating capacity, much of which will continue to come from coal, they will need improved technologies such as combustion turbines, combined cycle systems, and cogeneration that can

increase fuel efficiency by more than 25%. Further reductions of $CO_2$ are possible by switching from coal to oil and natural gas. Over the short term, oil and gas technologies should be considered environmentally sound for countries that would otherwise use coal.

- **Energy technologies not based on carbon resources.** Hydroelectric power already provides considerable amounts of non-$CO_2$ based energy, and wind energy, solar-thermal, and solar-photovoltaic technologies are other viable alternatives. These technologies will become more competitive as technical innovations and economies of scale reduce their costs. Nuclear power is also included by many as an environmentally sound technology, but problems of radioactive waste, decommissioning and its high cost make nuclear energy economically and environmentally less sound. Many environmentalists have similar reservations about large hydroelectric projects.
- **Agricultural and forest-related technologies.** This wide field embraces improvements in energy efficiency in agriculture (both directly and by reducing applications of fertilizers, pesticides and other chemicals) to control $CO_2$ emissions; use of new rice varieties, improved irrigation management techniques, or alternative livestock feeding practices that may contribute to reducing methane emissions; better forest management practices, afforestation, and the development of agroforestry practices to help slow rates of deforestation and increase potential carbon sinks; and technologies to increase agricultural output per unit of land to reduce pressures on forests.

This list illustrates the range of technologies at issue, the interrelations among the various technical solutions, and the difficulty of establishing a firm dividing line between technologies with potential for environmental improvement and those deemed important for development reasons. Decisions about the soundness of technologies must include both environmental and developmental criteria. Where environmentally sound technologies also reduce costs or enhance employment, they should form the core of technologies to be developed and transferred to developing countries.

## *Technological responses to environmental problems*

New efforts to reduce environmental degradation must call upon both "hard" technologies (machinery, tools, equipment) and "soft" technologies (management practices, know-how). Considerable environmental improvement will come not simply from applying existing technologies, but rather from developing new technologies and practices suited to local conditions and from efforts to improve operational efficiency.

These observations suggest the need to discuss not just the transfer of environmentally sound technologies but also the ways in which technological change (in both North and South) can be altered in the direction of greater environmental sustainability. Given the difficulty of distinguishing between environmental and developmental technologies, the search for specific environmentally sound technologies must be balanced with efforts to improve the internal technological capabilities of developing countries.

## *The lessons of past research*

These comments suggest that the scope of required actions is far broader than is generally understood. Nonetheless, the urgency of resolving current environmental threats and the wider recognition of mutual interests between North and South should provide a fresh — and constructive — outlook on earlier debates in the relationship between science, technology and development. The following discussion examines key lessons from earlier research on North–South technology issues and suggests the relevance of these debates to current environmental analyses

It is widely agreed that technological factors (and the capacity of a country to use these factors in achieving national development objectives) are among the key determinants of successful growth and development. Technological change may be induced by the generation of new knowledge through basic and applied research, the diffusion or transfer of new technologies both within and across national boundaries and their incorporation in productive activities, and the process of incremental improvements over time to production systems.

These three technology sources, it should be noted, are not isolated from each other. In order that science and technology realize their potential contributions to development, several activities spanning all three sources must be carried on simultaneously.

## *Knowledge*

Historically, productive knowledge has been created by people as they attended to their everyday economic activities. Over time, people may recognize, for example, particular characteristics of certain seeds, the success of patterns of crop rotations or of intermixing different plants to increase yields. Systematic processes for increasing the knowledge base are a fairly recent phenomenon, generally the preserve of universities and educational systems. Recent decades have witnessed newly devised structures of public and private research laboratories focusing on issues of basic knowledge and their application: it is this last category that is normally captured in national research and development (R&D) statistics.

We know that scientific knowledge is not always directly translated into technological innovation and that, too often, developing-country policies and international cooperation are biased toward supporting and promoting basic scientific capacities. That being said, however, there is a tremendous need for greater scientific and technical skills and increased research capacity in the developing countries. Three considerations support this observation.

- It is increasingly evident that domestic scientific and technological capacity is the most important factor determining the success or failure of effective technology transfer.
- Increased research capacity will allow developing countries to participate to a larger extent in debates over issues of global change.
- Finally, increased scientific capacity will allow developing countries to select and modify the most appropriate solutions to their needs.

If greater scientific and research capacity is to lead to success, attention must also be given to the efficiency of its creation in the South. Like economic efficiency, the efficiency of utilizing skilled personnel and scientific resources in developing countries is low. This inefficiency is due to many factors: inadequate physical facilities, low pay and lack of incentives for applied, problem-solving research, lack of linkages to users and to scientists in other parts of the world, poor access to information, and lack of experience in problem definition and management. Solving these shortcomings requires scientific cooperation between North and South and among Southern countries themselves.

A key linkage in the utilization of scientific and technological knowledge lies between producers and users of knowledge. In the late 1970s, a study of science and technology policy instruments (STPI) noted the intimate connection between production activities, related financial and economic decisions, and the "technology variable." Ideally, production and technology generation should be closely coupled, so that user problems lead research and development efforts; as solutions are proposed they are continually tested and adapted, providing new problems to be tackled and, hence, new directions for research. Unfortunately, the STPI study showed that such links are often weak or non-existent. Recent studies on university-industry linkages confirmed this finding, but also suggest that a number of innovative efforts to link public sector research institutions with private sector users could be undertaken.

Strategies to strengthen knowledge-creation capacities in developing countries must also contend with important changes in the nature of technological advances. Among these are the increasing interdisciplinary, science-based nature of technological change; trends toward privatization of research; and the growing internationalization of the research and development process. The implications of such trends for developing countries are far from clear, but they will certainly affect the costs and risks of basic scientific research in these countries, the need for collaborative efforts both within and among countries, and interaction between producers and users of technologies.

Knowledge creation may also involve the recovery and reintegration of traditional knowledge. This knowledge can be applied to several areas of environmental concern (such as low-input agriculture) that present considerable challenges for the South.

## *Technology transfer*

Technology transfer takes place when an existing technique is moved from one location to another. It may move from a research laboratory to a production location or from one production location to another. Transfers can take place within a single firm, a country, or across international boundaries. However it occurs, technology transfer remains a crucial element of any effort to deal with current environmental threats.

Of all the developmental gaps between North and South, the disparity in scientific and technological resources is especially acute. Despite efforts to develop local capacities in developing countries over the long term, in the medium term there will be a continuing need for technology transfer. Efforts to strengthen local innovative capabilities are in no way at odds with making existing technologies available to the South. Technology transfer and innovation are not polar opposites; instead, technology transfer can, under appropriate circumstances, contribute to the strengthening of indigenous technological capabilities.

Initiatives to increase the supply of technology to developing countries from abroad must be increased if current trends in technology flows are to be reversed. During the 1980s, Africa and Latin America watched important channels for technology transfer disappear as a result of low growth rates and high debt: these channels included capital goods imports, foreign direct investment, and training and technical assistance.

Meanwhile, increasing competition, rapid technical changes, and the resulting increase in the costs and risks of innovation have forced many multinational corporations (MNCs) to increase cooperative activities in technology development and production (cross-licensing of patents, joint R&D activities, new forms of product and process development partnerships). The increasing competition and larger numbers of technology suppliers should allow the South to increase its options and obtain better terms for technology transfers. However, greater collaboration among MNCs may lock developing countries out of an increasingly important source of technological advance.

## *Incremental technical change*

Radical breakthroughs in microelectronics, biotechnology and other fields often overshadow the equally significant role of incremental technical change. Incremental technical changes are developed and incorporated every day in any type of production unit whether it is a farm, factory, or service team. Technology users continually improve new machinery or processes, develop new applications, reduce input costs, and adapt the original innovation to local demands and conditions.

Since the late 1970s, several studies of firms and sectors in developing countries have highlighted the importance of incremental technical change. Earlier questions about whether to import technology or develop it locally, or questions about labour-intensive versus capital-intensive technologies, have given way to a recognition of the essentially dynamic nature of technology. Technology decisions are no longer seen as a one-off choice but as an ongoing series of decisions that must focus on continuous improvements.

The literature concludes that the impact of incremental technical change on productivity is astounding. At times, it can outweigh the impact of a completely new technology. Yet there is nothing automatic about this incremental process. Learning does not occur in all firms, but depends on a conscious decision by management to invest resources in training, organizational changes, and technical assistance.

Incremental technical change may also produce impressive rates of increase in the efficiency of energy and other natural resource use. Enos' ground-breaking 1962 study of American oil refineries over 30 years found that small, ongoing processes of technical change not only increased labour and capital productivity, but also resulted in over 50% savings in energy and other material inputs per unit of output. More recently, de Larderel (in UNCSTD, 1991) cites evidence from a survey of Dutch firms, in which as much as 30% of the prospects for cleaner production involved relatively simple housekeeping measures (fixing leaks, separating waste streams to allow recovery, etc.). The scope for relatively low-cost, incremental improvements in the environmental costs of production is clearly significant.

Similar evidence about technical change exists for developing countries. Technology transfer specialist M. Bell states that the most important source of productivity improvements for developing countries will continue to be incremental changes within existing production facilities, rather than entirely new generations of technology. He argues that, without sustained efforts, the transfer of novel technological systems may result in limited and short-term improvements in efficiency. Bell notes that improvements in resource use are closely linked to increased productivity of capital and labour. As a result, reductions in levels of $CO_2$ emissions and other pollutants can be combined with efforts to improve the economic efficiency of production in developing countries.

## *The Technology Market*

In development debates during the 1950s and 1960s, science and technology were considered public goods. It was assumed that the vast body of world knowledge could be picked off the shelf by developing countries to meet their needs. This accessibility would provide the developing countries with an advantage over countries that industrialized earlier, allowing them to "leapfrog" over the gaps between themselves and the industrialized countries.

In a similar manner today, many commentators suggest that technology transfer will allow developing countries to bypass the phase of development experienced by industrialized countries that was noted for intensive energy and materials consumption — and widespread pollution. Whether this hope is realized in the current context will depend on how well the ground is prepared for successful technology transfer. The following discussion looks at changing perspectives on the nature of the market facing Southern purchasers of technology, at the costs and benefits of transfer for technology suppliers and at some of the features of the market for environmentally sound technologies.

By the mid-1960s, developing countries were complaining about the scarce supply of technology available to meet their development objectives and about the control by MNCs of what few supplies existed. The earlier view of shelves bursting with technology was questioned increasingly. Instead, researchers like C. Vaitsos began to emphasize the process of "technology commercialization" or technology trade and to examine the nature of the market through which technology is transferred to developing countries.

Vaitsos and others argued that technology transfer is governed by a bargaining relationship between suppliers and recipients. In this relationship, purchasers are at an inherent disadvantage, owing to two factors:

- **The nature of technology itself, which is highly complex and cannot be evaluated thoroughly by buyers before a particular transaction.** As K. Arrow wrote in 1962, every commercial transaction of knowledge and information contains an inherent asymmetry: sellers know what they are selling and buyers must remain to some degree ignorant of what will be purchased. The problem is exacerbated in the case of Southern firms, which are typically smaller, less experienced, and technologically weaker than suppliers. The buyer suffers a further information disadvantage in seldom knowing what was paid for similar transactions in the past.
- **The oligopolistic or even monopolistic nature of the international market for technology.** New definitions of the MNC locate the core of its behaviour in its command of technology and the objective of maximizing profits from its technological assets. Technology suppliers have thus been able to combine ownership of technology, dominant market power, access to financial resources, and skilled personnel to extract advantageous agreements from developing-country firms and governments. These agreements resulted in high costs to the recipients — both financially and in terms of restrictive clauses.

## *Getting a good deal*

More recent research reconsiders some aspects of the 1970s view of the technology market. The number of technology suppliers in industrialized countries and, in some cases, in developing countries themselves has increased. The rising costs of R&D and the need for extensive markets to recover these costs has made large firms take greater interest in technology transfer activities. Studies by M. Bell and Scott-Kemmis also demonstrate that the Southern firm often leads in initiating the transaction, searching among a variety of suppliers in an attempt to extract a more favourable "bargain" (Bell and Scott-Kemmis, 1988).

At the same time, the importance of small and medium enterprises (SMEs) as technology suppliers is increasing. Since these firms suffer some of the same financial, informational, and human resource constraints as their Southern counterparts, their bargaining relationship with developing-country purchasers may be more equal than would be true of MNCs. Of course, smaller companies do not have the resources for large investment projects and therefore cannot replace MNCs entirely. But in a number of environmental sectors (waste treatment, energy conservation systems and management, some areas of biotechnology, etc.), smaller firms are likely to be important suppliers.

## *Small Enterprises As Technology Suppliers*

Will the increasing role of small and medium enterprises (SMEs) as technology suppliers hold benefits for developing country firms and governments? For Southern partners, agreements with SMEs could offer greater flexibility in sources of supply, equality in bargaining power, and the expectation that the technology will be more appropriate.

These prospects underpinned a collaborative project on SMEs as suppliers, carried out between 1987 and 1990 by a network of researchers from six developing countries (Argentina, Brazil, Mexico, India, Singapore and South Korea) and seven industrialized countries (Canada, France, Germany, Italy, Japan, the United Kingdom and the United States). Researchers studied 114 examples of technology transfer involving 106 supplier firms.

The picture that emerges is mixed. On the one hand, the bargaining position of recipient firms vis-à-vis SMEs may be relatively strong. The majority of supplier firms in the sample had no previous international experience, whereas recipient firms generally had at least some previous experience with technology imports. On the other hand, most of the SMEs were best characterized as small oligopolists occupying large parts of the domestic (and in some cases international) market in narrow product niches, giving them strong bargaining positions. SMEs are not alternatives to MNCs as suppliers of technology; at best they are only complementary (Niosi and Rivard, 1990, 1540–1541).

Not surprisingly, most of the supplier firms showed a preference for arms-length transactions, presumably because of the greater transaction costs involved in direct investment. Yet in a significant minority of cases, supplier SMEs opted for 100% equity investments rather than licensing or joint ventures — a factor the researchers attribute to the highly intensive nature of research in many fields of SME activity and the consequent need to protect key technological assets. The researchers also found, on average, that transfers were deeper than anticipated. They often involved the transfer of an entire range of product, process and organizational technology and there was a much higher commitment from SMEs to training than had been expected.

Despite this reappraisal, it remains true that the nature of technology creates an information asymmetry that will shift the balance of bargaining power in favour of technology suppliers. Consequently, a key constraint facing developing countries is the difficulty of matching their needs with appropriate technological solutions and finding alternative sources of technology supply. These constraints are all the more binding in new and emerging fields, where trends in technology development are uncertain, corporate secrecy prevails, and sources of supply may span several industrial branches.

## *Costs and benefits to technology suppliers*

The substantial costs associated with transferring technologies have a crucial influence upon the willingness of suppliers to make the technology available. These costs determine to a large extent the channels of transfer employed and what technological knowledge is transferred.

In a study of 26 technology transfer projects, D. Teece found that costs grew higher the more complex the technology to be transferred and the larger the knowledge gap between the supplier and recipient. Costs were also significantly higher when the technology was being transferred for the first time. F. J. Contractor outlined three types of costs: direct costs of the transfer (travel, training, personnel, documentation, and related costs), opportunity costs, and unrecoverable development costs. Niosi and Rivard further identify two types of opportunity costs. One is the potential cost of market loss and competition by the recipient. The other, which is often more important for smaller technology suppliers, is the opportunity cost of the skilled personnel used in the transfer process who could otherwise have been used more profitably in other activities.

Costs are lowest when existing designs, drawings, and specifications are copied and shipped to the recipient. Costs increase as more transfers occur of knowledge and skills that are unsystematized, in other words the individual expertise of specialists. Costs also grow as more training is provided to recipient firms and rise higher still if the technologies have to be modified for smaller markets or for different demand patterns and resource endowments in the recipient countries. Opportunity costs increase if skilled personnel are used and if the transfer has a negative effect on existing or potential export markets.

Despite these costs, technology suppliers can still reap long-term benefits, quite apart from direct payments for technology transfer. Such benefits take several forms and, in many cases, are not limited to the firm in question, but instead accrue more broadly to the supplier country.

- **Expansion of export opportunities for spare parts, auxiliary equipment, and related products or technology.** In emerging fields, early entry as a technology supplier may result in substantial advantages over competitors—not only because of the need for recipients to ensure standardization of supply, but also because of the imperfect information on alternative sources of supply.

- **Increased efficiency of the transfer process itself.** There are substantial learning effects associated with international technology-transfer operations for supplier firms as they master the legal, managerial, and technical challenges involved in the successful transfer of process or product technology to a different competitive environment.

- **Enhanced competitive position of supplier firms vis-à-vis international competitors.** In cases where the domestic market is small or the upstream costs of technology development are high, international technology-transfer operations may be an important means of reaping economies of scale and a precondition to lowering unit production costs.

- **Improving the productivity of input and component suppliers, whether these are affiliated firms or arms-length contractors.** Particularly in final assembly industries (electronics, automobiles), the profitability of the firm depends crucially on the efficiency of input suppliers. Industry is also moving toward more flexible, arms-length relationships as a means of providing the necessary flexibility to adjust to shifts in demand and consumer preferences.

- **Two-way flows of knowledge.** There may be substantial scope for supplier firms to benefit from process or product adaptations pioneered by recipient firms. Such reverse transfers are more likely to result from transactions that involve active and ongoing contact among the parties, rather than relatively passive sales of equipment or licensing of design information. This type of ongoing technological cooperation between firms in industrialized and developing countries is not common, but may hold significant promise.

Firms' calculations of costs and benefits will be affected by two additional factors. First, many of the "dynamic" benefits outlined above will only materialize over time. Small firms with little international experience may not be able to internalize the short-term costs of transfer while they wait for longer-term benefits to take hold. Financing may be required to induce smaller firms to become involved in transfer operations—particularly if there is pressure for longer term, more intensive interaction with recipients.

Second, many of the benefits of technology transfer to the supplier firm are only partly appropriable by that firm. Once again, smaller, more specialized firms may not be able to capture the downstream benefits of transfer where they affect future export markets.

## *Technological capabilities*

In their early critiques of technology transfer, developing countries focused largely on what they considered the excessive costs of technology transactions and the many restrictive clauses imposed on recipients by suppliers. Such concerns formed the basis of several interventions by developing country governments to increase the information available to recipients, strengthen the bargaining capacity of recipient firms, and outlaw practices deemed to violate national interests.

A second set of criticisms centred on the inappropriateness of imported technology — in terms of its capital- and skill-intensity, reliance on imported rather than locally available inputs, and orientation to the needs of higher income consumers in industrialized countries. Production using these technologies reduces employment, heightens foreign exchange constraints, and limits backward linkages to the local economy. In addition, this path may lead to a dual economy, in which a modern sector exists alongside growing poverty and unemployment.

These are undeniably important points. Debates about environmentally sound technology cannot be divorced from earlier concerns about the economic, social, and cultural appropriateness of imported technology. Neither can the rush to stop environmental degradation detract attention from the terms and conditions under which technology is supplied.

Increasingly, attention is being focused not on the costs and characteristics of imported technologies, but rather on the factors affecting the creation and maintenance of technological capabilities in developing countries. This attention is due to the fact that the limited bargaining capability of Southern firms, inappropriate technology choice, and insufficient linkages with the local economy can only be overcome by efforts to increase the internal capabilities of developing countries to select, adapt, and develop appropriate technologies. It also results from a reappraisal of the linkage between technology imports and technological capability. Most dependency literature argues that transfers of technology could be cost minimizing for individual transactions, but would in the long term have negative effects on indigenous capacity. However, recent case study research, as well as the experience of South Korea and Taiwan, suggest that, at least under certain circumstances, transfer of technology can strengthen technological capabilities in developing countries. Efforts must be taken to ensure that badly needed technology imports contribute to, rather than frustrate, efforts to build up such local capabilities.

In essence, technological capability refers to the skills, abilities, and experience needed to select, use, adapt, and create technology. Indicators of technological capability would include: the capacity of the recipient firm to define its technology needs and negotiate with suppliers; the ability to efficiently operate imported technology; the capacity to undertake routine repairs and maintenance; the ability to analyze production facilities and modify equipment to increase capacity and reduce costs; the ability to plan, design, and execute expansions of capacity; and, finally, the ability to generate a series of technological innovations to improve production.

## *Energy Efficiency In The Fertilizer Industry, Bangladesh*

A. Quazi's study of the fertilizer industry in Bangladesh provides interesting insights into both the low levels of energy efficiency often achieved in developing country installations, and the reasons for the poor performance.

The study of energy efficiency in two urea fertilizer plants remained below initial design levels — in direct contrast to the situation noted for similar plants in industrialized countries. Only very slow rates of improvements in energy efficiency were noted with no significant plant adaptations over the eight-year period of study.

This performance reflects the strategy adopted by plant managers with respect to acquisition and strengthening of indigenous technological capabilities. Improvement and modernization of the plants was dependent almost entirely upon outside managerial and technical expertise. Rather than engendering an ongoing, on-site process of technical change, this situation led to a piecemeal, "stop-and-go" trend in productivity: while efficiency (including energy efficiency) rose as a result of the application of imported expertise, levels of efficiency began to fall once outside engineers and managers were withdrawn.

In most cases technology transfer has not allowed recipient enterprises to accumulate such technological capabilities. In a study of the transfer of petrochemical technology to the Middle East, the United States Office of Technology Assessment concluded that although the volume of technology transactions had increased, "technology transfers (whereby recipient gains improved capability to operate an industrial facility) have been limited." In 1988, H. Hill stated that "technology transfer in Indonesia rarely moved beyond production."

In other cases, however, the results are far more encouraging. One frequently mentioned example is the USIMINAS steel plant in Brazil, which not only successfully assimilated and adapted imported technology, but used the knowledge to generate and commercialize new technologies.

Clearly, then, there is no automatic link between technology imports and the development of technological capability. As Bell notes, technology transfers can be distinguished in terms of their "technological content" — that is, the knowledge, skills, and capabilities imparted to the recipient. In some cases, this technological content is relatively low, consisting largely of capital goods, engineering and managerial services, and product designs. In other cases, additional skills and know-how for operation and maintenance of imported technology are included. In both instances, only production capacity is transferred to the recipient. Bell contends that only where there is a thorough transfer of the knowledge, expertise, and experience needed to generate and manage technical change can we speak of the accumulation of technological capacity by a recipient.

## Success factors

The evidence suggests that two factors are crucial in determining the extent to which technology transfer contributes to building indigenous technological capabilities.

The first is the intensity of contact between the supplier and the recipient. Active, ongoing contact between recipient and supplier is crucial to the effective transfer of skills and knowledge. This type of contact does not mean, however, that direct equity involvement of suppliers is essential. Far more important than the contractual form of a transfer is the extent of knowledge acquisition. In this regard, training is crucial. Unfortunately, recipient firms and countries all too often underemphasize or ignore training. For instance, in an analysis of over 600 petroleum exploration contracts, T. Turner found that only 14% made any provisions regarding training, employment of nationals, and local technical services, and concluded that the contracts displayed little concern for acquisition of critical skills.

Mineral processing specialist A. Warhurst confirmed the importance of training links in a study of the mining industry. Warhurst argues that Northern mining companies are beginning to apply their latest, cleanest technologies to developing-country operations in a bid to offset high development costs, improve their public image, and avoid future regulatory barriers. Whether developing countries profit from such a change in corporate practices will depend upon how technology-transfer agreements are structured and on the ability of recipient firms and countries to build adequate knowledge transfer and training components into licensing agreements and joint ventures.

The second factor in strengthening local capabilities is the strategic orientation of the recipient enterprise. In a study in India, N. Nath concludes that "the subsequent update or activities undertaken by the host country enterprise" is critical to successful transfers. These efforts require sound knowledge before transfer, a rigorous search for sources and intensive participation at all stages of project planning and implementation. J. Enos and W. Park confirm that local efforts have been the most significant factor in Korea's success in technology transfer. Other work by A. Desai and P. Mihyo suggests that where local capacities to search, select, and negotiate for technologies are absent, government regulation on its own has been of little value in augmenting domestic technological capability.

# Options

## *Ensuring a wide choice of initiatives*

North-South technology transfer and cooperation involves difficult choices. It required detailed action plans, setting targets and modes of implementation, and outlining the financial, technical, and institutional requirements.

As well, effective action in the area of technology transfer and cooperation must involve a number of different actors — national governments, private sector firms, international institutions, and non-governmental organizations. Securing consensus among the various actors may be a difficult process and should not deter individual actors or smaller groups of actors from opportunities for immediate action.

Moreover, the global environmental debate is still characterized by uncertainty, not only regarding the severity of the threats but also regarding the appropriateness of various responses. This uncertainty is compounded by the rapid changes in many relevant fields of technical knowledge, and by the fact that the effectiveness of any given technological solution will be dramatically affected by the conditions in which it operates.

Under such conditions of uncertainty, the most appropriate response may be to pursue a variety of initiatives simultaneously. Although there may be certain efficiency losses, these are likely to be less important than the cost of negotiating more comprehensive plans of action or the danger of investing too many resources in what may be a false lead. Given the broad range of actions required, no single actor or group of actors can address them all. Pursuing a number of actions will allow for the participation of different actors, and increase the potential for contribution of specialized knowledge available.

## *Pursuing areas of mutual interest*

We all share the same planet. There are, at the same time, limits to the degree of mutual interest when issues of economic and political power are involved. In the South there are fears that the sacrifices and burdens will fall unfairly on the poor, and intensify existing inequalities. But the notion of mutual interests can direct our attention toward possible "win-win-win" solutions — that is, initiatives that meet the developmental needs of the Third World, the commercial needs of technology suppliers, and the environmental needs of the planetary ecosystem.

New evidence suggests that protecting the environment and encouraging economic growth and development are not mutually exclusive, and that the application of environmentally sound technologies can even result in increased economic efficiency. A recent report by the World Resources Institute (WRI) argues that advances in the fields of biotechnology, information systems, and advanced materials hold out the promise of a technological "transformation," in which pollution and materials consumption per unit of output decline in step with increases in economic output. As mentioned in the previous chapter, incremental improvements to existing facilities can yield economic and environmental benefits.

In theory, then, it should be possible to formulate courses of action that will respond to environmental imperatives without sacrificing the developmental aspirations of the South, and without expecting technology suppliers to forego commercial benefits. Yet, there remain formidable barriers to the realization of these solutions.

Financial constraints are important because of the need for financial support to overcome short-term costs. In addition, the "public good" characteristics of many environmental technologies mean that recipient firms cannot hope to reap all the benefits from the application of these "green" technologies. In such situations, additional compensation (tax incentives, government funding of export development missions) may be necessary.

Since most environmentally appropriate technologies for the South are not state of the art, financial considerations are not usually a problem. The rapidly changing technology frontier, combined with intense competition among suppliers, may make suppliers more willing to transfer even very new technologies.

There are also important information obstacles to negotiating "win-win-win" solutions. As pointed out earlier, technology purchasers typically face extreme disadvantages vis-à-vis suppliers, in terms of their inadequate knowledge regarding domestic technology needs and the range of technologies potentially available to meet those needs. There are also informational constraints on the supplier side. Young firms and firms working in emerging fields have a difficult time estimating potential markets. In addition, technology suppliers may find out there are few if any buyers — either because the field is still new, because the benefits of the technology have the character of a public good (with few individual buyers willing to become involved), or because the firm lacks experience in overseas markets.

Finally, there are institutional constraints that must be considered, such as the various ways in which domestic policy in both recipient and supplier countries works against successful technology transfer: for example, intellectual property regimes, pricing policies, and taxation measures. There is a need to reform existing research, and research policy institutions and, in some cases, create them in countries where they do not exist so they can strengthen local capacity to import appropriate technology.

## *Building long-term capabilities*

As Joly and Bandelier (1988, 14–16) note, short-term application of existing technologies may alter the scope for longer term development and application of new technological solutions. The application of scrubbers, for example, in thermal power plants may slow the introduction of environmentally preferable technologies, such as fluidized bed combustion, because of lower investment costs. In addition, B. Arthur (1990) pointed out that initial technological solutions may in many cases become "locked in", with the result that costs of switching to new standards becomes prohibitive, even if they hold out the potential of efficiency gains. This suggests a note of caution in terms of latching on to emerging technological solutions — particularly for developing countries where resource constraints may make the problems of "lock in" even more insurmountable.

Clearly, it is impossible to predict the nature of the interrelations among various technologies, or to second-guess future patterns of technological advance. What the above examples illustrate is the importance of capacity-building. **The ultimate goal of any action in the field of environmentally sound technology should not be to apply particular technological solutions, but to enhance the capabilities of developing countries to select, import, assimilate, adapt, and create the appropriate technologies.** This is a matter of enhancing "generic" technological capabilities rather than pursuing actions related specifically to environmental technologies.

This by no means implies that short-term action is not required or that technology transfer is unimportant. But it reinforces once again that transfer of "clean" technologies is only part of the solution. Concern with the economic and environmental efficiency of a given technological solution needs to be matched with a concern for its integration into the local productive structure, the conditions by which it is acquired, and the extent to which "hardware" imports are accompanied by effective transfers of knowledge and capabilities.

The pages that follow set out some more concrete avenues for action, grouped around four broad objectives. Priority is given to the three criteria outlined earlier: ensuring a wide choice of actions, overcoming the barriers to "win-win-win" solutions, and building long-term capabilities in each of these areas.

## *Clarifying the rules of the game*

Attention must be given to the broad principles that should govern cooperation between North and South in their efforts to facilitate technology transfer and strengthen the technological capabilities of developing countries.

The issue of intellectual property rights is perhaps the most contentious facing the technology transfer debate. Differing perspectives exist on the nature of scientific and technological research, and the appropriate distribution of the benefits flowing from such research (Belcher and Hawtin, 1991). On the basis of recent public pronouncements from Northern and Southern representatives, there seems to be little scope for a compromise. Yet, there are some signs of hope — notably the progress that has been made in the past few years on the issue of "farmers rights" (Keystone Center, 1991) — which suggest that what were once seen as intractable issues can in some cases be resolved. There are also indications of important changes in the attitudes of some Third World governments (most recently Mexico) toward intellectual property rights, which may lead to equally important shifts in North–South negotiations. On the Northern side, however, positions have been far more uncompromising, with the United States in particular exerting pressure on developing countries to extend protection.

Recognition of intellectual property rights is essential to the development of much-needed technologies. At the same time, however, developing countries should resist pressures to unilaterally extend property rights, particularly into new and controversial areas like the patenting of living organisms. Instead, priority should be given to ongoing multilateral efforts to find a compromise between Northern and Southern positions on this issue. While long term solutions take time, limited actions on patent protection can be taken to ensure the flow of technologies and serve as confidence building measures.

On the issue of concessionality, the challenge is to marry Northern concerns to recognize the commercial nature of most technology transfer with Southern demands for favourable access. A compromise position may be possible, resting on a distinction between the terms upon which technology is purchased from a commercial supplier, and the terms upon which financing is made available to developing country purchasers. Such an agreement would reaffirm that in the case of privately-owned technologies, market rates should form the basis for compensation to owners of technology. On the other hand, however, developing countries would be provided with concessional financing to allow them to make such purchases, and assured that such financing would be additional to existing commitments for development assistance.

In essence, this is a recognition of the broader principle, now enshrined in the Rio Declaration, that North and South have "common but differentiated" responsibilities with respect to global environmental degradation. Due to their greater contribution to current problems, and the greater resources at their disposal, Northern countries should shoulder the greater burden of countering global environmental problems — both by taking immediate action to reduce their own contributions, and by assisting developing countries to do the same. If developing countries are to compromise on the issues of concessionality and intellectual property rights, strong commitment by industrialized countries in the area of burden-sharing is essential.

It is also important to recognize that the imperfect nature of some segments of the technology market means that "market rates" may be excessive, and may be accompanied by excessively restrictive conditions of transfers. As a result, there is a need for renewed discussions on some form of code of conduct to guard against abuses of strong market positions.

## *Increasing the supply of technology from abroad*

This is the area that has received the greatest attention to date. As has been argued throughout this report, the problem of applying environmentally sound technologies in developing countries cannot be limited to the much narrower issue of increasing the flow of existing technologies from North to South.

Nonetheless, increasing the flow of environmentally sound technology may counter some of the other trends at work in the international technology market. North to South technology flows have stagnated over the past decade because of indebtedness, declining industrialized-country investment, cutbacks in aid appropriations, privatization of research, and because of the growth of collaborative arrangements among Northern firms.

Ensuring an adequate flow of technology depends on the efforts of North and South to create a market for environmentally sound products and services. A long-term response must deal with the structural factors that limit demand for imported technology in the South, such as small effective market size, foreign exchange constraints, and lack of infrastructure. Ultimately, this must involve action to resolve the underlying problems (debt burdens, protectionism, stagnant aid flows, ineffective macroeconomic stabilization) that limit both foreign and domestic investment.

The appropriate actions depend crucially upon the type of technology in question. As a start, it is instructive to consider four technology categories: proprietary, public domain, "emerging" and precommercial research, and "soft" technologies or know-how.

## *Reducing CFC Use in Mexico's Electronics Industry*

Mexico uses close to 400 metric tons of CFC solvents annually in its burgeoning electronics assembly industry. Efforts to lower this figure have led to an innovative partnership involving electronics enterprises, the Mexican government's environmental agency (SEDUE), the US Environmental Protection Agency (EPA), and Canadian-based electronics manufacturer Northern Telecom.

In seeking to remove CFC use from its operations, Northern Telecom developed a spray misting technology that eliminates any need for CFCs in cleaning residue from printed circuit boards. This environmentally sound process is also economically feasible and efficient.

In March 1991, Northern Telecom, SEDUE and the EPA launched a training and demonstration project on CFC solvent conservation and elimination in the Mexican electronics industry. Northern Telecom will share its experience in the implementation of a CFC-reducing technology and coordinate a series of training programs for Mexican companies.

Multilateral financing plays a key role in the project since the Multilateral Fund established under the Montreal Protocol has financed some of the capital costs of conversion to the new process. But the project also illustrates how long-term corporate interest can be a potent force for North–South technology transfer. In addition, the project highlights the potential for collaboration among private sector technology suppliers. A key aspect is the involvement of the Industry Cooperative for Ozone Layer Protection (ICOLP), an association of industrial users of CFCs founded in 1989 to coordinate the worldwide exchange of information on CFC alternatives. The project will mount demonstrations at ICOLP member facilities and use ICOLP's on-line data base, OZONET.

## Proprietary technologies

In the case of proprietary technologies, intellectual property issues remain a high hurdle to overcome. In the absence of an agreement, however, there may be considerable scope to increase the transfer of certain types of proprietary technologies.

Companies may be willing to transfer recently developed technologies in cases where these do not represent part of their "core" technological capabilities, and where the spread of such technologies to subsidiaries and nonaffiliated suppliers improves long-term profitability. In industries such as electronics and automobiles, the wide network of equipment and component suppliers involved (many without equity links) means that "sharing" technologies may be an essential part of a competitive strategy.

There may be considerable scope for technology cooperation among noncompeting users. This is the case, for example, with a proposed network of utility companies in Brazil, China, Europe, India and North America, which would sponsor collaborative research and technology development related to climate change (USAID, 1990).

In some fields it may be possible to use public interest provisions in existing legislation as a vehicle to encourage the diffusion of proprietary technologies.

Finally, there may be scope for the creation of specialized brokering services to mediate between the owners of proprietary technology and potential users in developing countries.

## Public domain technologies

For more widely available, public-domain technologies, the barriers are likely to be less legal and financial than informational. Mechanisms to increase the flow of such technologies might include donor government funding of export development missions, particularly for small, specialized firms; improved provision of market information to smaller and less experienced suppliers; or support to brokering services.

## *Precommercial research*

In the case of emerging technologies and precommercial research, much depends upon whether research is public or private. In the latter case, significant progress can be made by donor countries in funding research partnerships between developing countries and Northern researchers in university or public sector institutions. A good example of this is IDRC's cooperative research grants program, involving Canadian and developing-country scientists. At a more ambitious level, multilateral efforts can be taken to fund precommercial research in specific areas, similar to the CGIAR (Consultative Group on International Agricultural Research) system in the field of agricultural research.

### *Brokering in Biotechnology*

Recent advances in agricultural biotechnology could play a crucial role in meeting the food needs of an expanding global population. Such advances can be achieved by developing pest-resistant plant varieties and increasing the use of biopesticides and biological control systems.

Advanced biotechnology applications are, however, increasingly proprietary due to the dominance of MNCs in this sector. This is in stark contrast to 'Green Revolution' high-yielding varieties, which were largely under the control of national and international public sector research institutes. Serious doubts about the ability of developing countries to secure access to biotechnology applications have been raised because of the growing infrastructural and investment contraints.

One response to this situation has been the recent formation of the International Service for the Acquisition of Agri-Biotech Applications (ISAAA), a non-profit international organization to facilitate the transfer of biotechnology applications. Still in its infancy, the ISAAA's goals are to assist developing countries by providing assessment, monitoring, 'brokering', and funding services. In addition, the group matches needs with appropriate technologies, and offers counselling on biosafety and regulatory procedures.

Early examples of ISAAA's work include an arrangement by which Monsanto Corp. will transfer coat protein genes to a Mexican research institute to control potato viruses, and a project to transfer a cold DNA diagnostic probe for detection of black rot, developed by researchers at Washington State University, to the Asian Vegetable Research and Development Centre (AVRDC) and its client countries in the Third World.

In cases where basic and precommercial research has been largely or completely privatized, the barriers to transfer are greater. Strategic partnerships in semiconductors, telecommunications and the like span national boundaries, facilitating the international flow of precommercial research, but have not involved Southern countries. The future involvement of Southern firms in such schemes is doubtful due to their limited scientific capabilities.

## *Strengthening Environmental Management Capabilities*

Discussions of technology transfer inevitably focus on the transfer of "hard" technologies (machinery and equipment). Equally important, however, are the "soft" technologies (skills and know-how) necessary to maintain and adapt imported equipment. Efforts to upgrade environmental management skills are just as vital as imports of "cleaner" technologies.

The Environmental Management Development project in Indonesia (EMDI), a joint effort of the Indonesian Ministry of State for Population and Environment (KLH) and the School of Resource and Environmental Studies at Dalhousie University in Halifax, Canada is attempting to tackle this issue. The project is designed to strengthen the institutional and human resource base for environmental planning in Indonesia. Currently in its third phase, the project is supported by the Canadian International Development Agency (CIDA), which will contribute CAD $31.1 million to the project between 1989 and 1994.

The project involves a variety of technical cooperation and training activities, spanning the following areas:

- spatial planning and regional environmental management (particularly the application of geographic information systems);
- environmental impact assessment, environmental standards, hazardous and toxic substance management;
- marine and coastal environmental management; and
- environmental information systems, environmental law.

The EMDI project also proceeds from the conviction that responsibility for environmental management must be shared among a variety of institutions. In addition to the lead role played by KLH, the project is also intended to strengthen the environmental management capabilities of central, sectoral and regional governmental agencies, universities, non-governmental organizations (NGOs), and private sector institutions. Linkages and exchanges with Canadian counterparts are designed to support the development of relevant skills and expertise in all these spheres.

## *Soft technologies*

Finally, in the area of "soft" technologies and know-how, there are a wide variety of mechanisms to facilitate transfer. Such know-how tends to be widely dispersed in most fields, with a few exceptions. There is considerable scope for South–South transfers in this area, and for various forms of "twinning" between Northern and Southern institutions. In addition, action to reverse the South–North flow of trained professionals is a crucial concern in this area.

## *Adopting technologies*

In the area of technology adoption, the key problem is the frequent lack of incentives for the application of more environmentally sound techniques; as a result, existing and readily available solutions, whether imported or locally developed, may not be applied as widely as is desirable.

The recent debate has viewed this problem as one of "market forces," focusing on distortions in factor prices (especially energy), on poorly developed capital markets and on trade restrictions that militate against the import of environmentally sound products and processes. Clearly, reorienting prices to redress the most glaring problems is urgently required. This, for example, is the intent behind discussions of possible "carbon taxes" on fossil fuel use, or more general taxes on energy use: in both cases, taxation would force energy users to "internalize" the social and environmental costs of energy use, and thus would alter the relative profitability of "clean" technologies.

It is also being recognized that market-based reforms on their own may be insufficient to alter prevailing patterns of technology use. In addition, a variety of nonmarket measures may be needed:

- More traditional "command and control" type regulations (pollution standards, regulatory practices) may be essential in at least some fields, particularly where price mechanisms do not function adequately.
- Financial or technical bottlenecks slow the shift to cleaner technologies. In such cases, public sector financial assistance, or publicly funded R&D, may play an important role.
- Developing-country governments can also have a considerable effect by reforming investment criteria for private-sector investments and by the judicious use of procurement provisions in public sector investment.

Donor countries can assist in the kinds of reforms outlined above through the provision of financial assistance and the furnishing of technical assistance for specific aspects of policy reform (e.g., regarding investment criteria). There are also several more areas where donor involvement might help to improve adoption of clean technologies:

- Funding of demonstration projects illustrating the technical and economic efficiency of environmentally sound technologies might help to overcome some of the nonfinancial barriers to technology adoption;
- Financial and technical assistance could be provided to promote technology-sharing arrangements among developing country firms, as a means of overcoming the high capital costs of many relevant technologies
- Assistance could be provided to improve the technical expertise of local and regional lending institutions in developing countries. Development banks and similar institutions play a key role in providing local funding for technology-transfer projects. Yet, such institutions frequently lack the necessary expertise to adequately assess the technical feasibility of investments.

It is widely accepted that ensuring effective use is at least as important as promoting the initial adoption of technologies. Research has established that efficient operation of a given technology is critically important; as a result, considerable effort must be expended to reach the operating parameters of a given technology. Moreover, since imported technology may be inappropriate to domestic conditions, a series of minor or major adaptations may be required to allow such technology to function effectively in developing country markets.

## *Assimilation of technology*

Assimilation is dependent on the broad conditions facing local firms: degree of local competition, trade, monetary and fiscal policy, and the availability of trained personnel. At the same time, however, there are a variety of more limited, concrete measures which can be undertaken:

- The feasibility of effective assimilation is determined by the conditions under which technology is transferred, particularly the provision of long-term training and technical assistance services by the supplier. Incentives can be offered to promote such involvement and in cases where such long-term involvement is not feasible, alternative sources of technical assistance could be developed.

- An adequate supply of trained human resources is essential to effectively assimilating new technology and engendering ongoing performance improvements. Attention should be given to incentives for on-the-job training and to effective training of engineers, scientists, and technicians.
- Finally, the development of technological capabilities is often the result of idiosyncratic firm-level factors. As a result, management training and demonstration projects may have a decisive effect on firm-level technical effort.

Strengthening developing countries' technological capabilities is potentially the broadest avenue of action: it encompasses efforts to strengthen local research and training institutes, develop long-term partnerships between Northern and Southern institutions, and promote more effective technological decisions within productive enterprises. The following areas are of particular importance: strengthening the scientific capabilities needed to adequately assess technology needs in developing countries; improving technology assessment and choice; and strengthening innovative capabilities of key institutions.

## National needs assessment

Developing countries must have adequate environmental scientific capabilities if they are to make correct assessments of their technological needs. Acquiring relevant scientific knowledge regarding environmental issues should be seen as an essential counterpart to any action on technology transfer.

A US document prepared for the June 1991 meeting of the Intergovernmental Negotiating Committee (INC) for the proposed climate change convention argues that if properly designed, country level needs assessments can themselves be an effective way of "transferring data, expertise, and analytical capabilities to host countries." The paper goes on to argue that the experience of the Montreal Protocol may offer important lessons in this regard. Under the Montreal process, industrialized countries volunteered to assist one or more developing countries in undertaking joint needs assessments, subject to a common framework developed at a workshop of participating countries.

For many developing countries, the financial, technical and logistical burden of national assessments may be overwhelming. While the Montreal Protocol experience is thus an interesting experiment, there will also be a need to explore more decentralized approaches, working from the regional or local level. Any needs assessment procedure must give careful attention to the methodology to be followed, and the type of training provided to local counterparts. In the area of climate change, this is most likely to take place via the Intergovernmental Panel on Climate Change (IPCC), which has endorsed a work plan to develop draft guidelines for national emissions inventories.

One final point must be stressed. Needs assessment should not be focused exclusively on identifying possible technological solutions. As decades of experience in supporting research for development have shown, a successful intervention must start by identifying the needs of the local population to ensure that solutions are effectively implemented. Even though inventories of potentially useful technologies are urgently required, it is crucial that needs assessment exercises not assume that solutions will be technological.

## *The Importance of Needs Assessment: Solar Dryers in Africa*

Donor preferences and disciplinary biases can derail good intentions in developing and diffusing appropriate technologies. This undesired outcome appears in a 1987 study of solar drying technologies in Africa by C. Wereko-Brobby, pointing to the value of needs assessment.

Following the oil supply and price problems of the 1970s, "governments in many developing countries, international funding agencies, and researchers operated on the single assumption that any activity that increased, or diversified, energy supply options would be good for the country in the long run" (Wereko-Brobby, 1987, 276). Therefore, research was directed to developing and diffusing particular renewable energy technologies, in this case solar dryers. This technology-push bias was made worse by the fact that research and development was conducted solely by technologists, with little or no input from social scientists.

The process did produce several technologically superior dryers. However, success in applying the improved designs was limited. The root cause, argues Wereko-Brobby, was the failure to adequately identify beneficiaries and assess their needs. Wereko-Brobby argues that technological innovation, when dealing with subsistence farming communities, should be the last piece of the research equation to be considered.

## *'Appropriate Technology' vs. 'Best Available Technology': Options For CFC Phaseout*

Since the signing of the Montreal Protocol in 1987, considerable efforts have been devoted to the development and application of alternatives to chlorofluorocarbons (CFCs). Multinational electronic companies have developed new techniques for cleaning electronic components, substituting water-based solvents or reducing the use of soldering flux itself. The switch away from the use of CFCs as aerosol propellants has also been rapid: aside from initial investment costs, non-CFC propellants offer significant cost savings over CFCs. The most difficult and costly change, however, will be the switch to non-CFC refrigeration technology — which is by far the greatest source of CFC use in developing countries.

To date, most of the emphasis has been placed upon two new chemicals: hydrochlorofluorocarbons (HCFCs), which contain some ozone-destroying chlorine but are less stable than CFCs and thus largely break down before reaching the ozone layer; and, hydrofluorocarbons (HFCs), which contain no chlorine. While the cost of switching to HCFCs or HFCs is relatively high, their use is being promoted both by Northern chemical companies (which see an opportunity to market new, proprietary technologies as a replacement for CFCs which are no longer protected by patents) and by developing country governments (which are justifiably reticent to accept 'second-best' alternatives which might widen the technological gap between them and the North.)

These may not be the only alternatives to CFCs. The *New Scientist* (30 June 1990, pp. 39–40) has suggested that there are cheaper alternatives to CFCs which may prove appropriate for many uses. These include the use of propane or ammonia as refrigerants, or the development of 'absorption refrigerators'. The latter use water as a coolant (with a chemical such as lithium bromide used as an absorbent) and in addition to replacing CFCs may dramatically improve energy efficiency.

The economic and technical feasibility of such refrigerants remain largely unexplored; however, their very existence highlights possible conflicts between 'best available' and 'appropriate' technologies, and between directions of technological change suggested by current commercial interest versus alternate directions. There is a compelling need for research into novel alternatives to CFCs to meet developing country needs, and for dissemination of information regarding such innovations.

## *Choosing the right technology*

Sound technology choice is the backbone of any strategy for international technology transfer. Unless developing countries have the proper knowledge to make informed choices among technological options, efforts to promote international technology transfer risk becoming overwhelmingly supplier driven, geared more to transferring available technological solutions than to responding to the needs of developing countries. The South faces severe disadvantages in terms of information available to it as well as its technical capacity to evaluate particular technologies.

To begin with, developing countries need better access to information on the range and performance characteristics of given technologies. There are now a number of inventories, information services, data bases and the like either in operation or in the planning stage to alter this fact.

In all likelihood, however, access to information will be limited by the insufficient capacity of recipient countries to use the available information. The design and implementation of information systems has to ensure that the appropriate clients are reached, and that the appropriate tools are available to promote diffusion of the information within supplier countries. In addition, there may be considerable room for the involvement of intermediary institutions that perform a brokering service.

To improve the technology-assessment capabilities of recipient countries, there are obvious needs for the provision of training support and personnel exchanges, both on a government-to-government basis and within productive enterprises. There is also a need for improved teaching materials, manuals, and assessment criteria to permit more effective evaluation of technology alternatives. This is important if developing countries are to resist the temptation toward the automatic application of "best available" technologies, and, instead, begin to investigate alternatives more appropriate to their domestic conditions.

## *Strengthening innovative capabilities*

Ultimately, an effective response to global environmental threats must also allow developing countries to create their own technological solutions. Innovative institutions in the South need support. Two specific points should be made regarding the types of capacity-building actions which are required.

- First, the past two decades have witnessed a shift in the locus of technological effort away from formal research institutions, and toward the productive unit; as a result, any strategy to improve the technological capabilities of developing countries must involve action at this level as well as broader based support to national and regional research institutes.
- Second, it is now accepted that innovations result from networks of institutions. Considerable emphasis should be placed on efforts to improve the capabilities of technology users and equipment suppliers—which are being recognized as an important source of innovation in industrialized countries. In addition, ongoing efforts to provide effective linkages between research institutions and technology users in productive sectors are crucial and should be a key focus of donor efforts to strengthen local systems of innovation.

There are a number of possible actions which can be taken to strengthen developing countries' innovative capabilities. Twinning programs between Northern and Southern institutions; enhanced scholarship support to developing country students; project and/or core support to existing scientific institutions; policy advice regarding the reform of incentives to private-sector research; enterprise level training in improved production design, maintenance and quality control — these are all examples of incremental, independent actions which can and should be pursued by a variety of actors.

## *North-South collaboration*

Given the economies of scale associated with scientific research and the limited resources available to most developing countries, however, some form of collaborative effort in this area is essential.

In this regard, there are two broad avenues of action. The first, exemplified by the United States' call for the establishment of major regional research institutes on global environmental issues, stresses the creation of new institutions charged with furthering environmental science, technology and policy. There are, of course, advantages to such an approach—particularly the ability to transcend the disciplinary boundaries of many existing institutions in order to attack problems from a more integrated perspective. Any such effort must learn from the strengths and weaknesses of existing bodies, such as the CGIAR system in the field of agricultural research. Specifically, there is a need to have greater participation by developing-country scientists, policy makers, and users of the research results in these institutions than has often been the practice.

On the other hand, in a climate of severe resource shortages a new regional initiative is likely to be counterproductive if it is at the expense of increasing the capacity of existing national institutions. For this reason, others argue for alternatives to the creation of new institutions. The UNCED Secretariat has proposed the establishment of regional capacity-building programs to support sustainable development in developing countries, which it argues would not require the establishment of new central institutions, but would instead involve mechanisms for coordination and cooperation among existing institutions. The experience of IDRC and other donors active in the support of development research will form an indispensable part of any strategy to reinforce and improve existing capabilities.

# Beyond Rio

In the wake of the largest-ever gathering of world leaders to discuss environmental and developmental problems, naturally there has been considerable debate about the success or failure of the Earth Summit. The almost universal endorsement of Agenda 21 and the approval of the biodiversity convention are to be lauded, but in many other areas — financial resources, technology transfer, institutions — progress was below expectations. In the end, however, the verdict on the success or failure of the Earth Summit will depend less on any of these specific achievements or shortcomings than on the processes which emerge over time and their relevance to the tasks before us. Attention must now shift to the enormous tasks of moving forward to concrete actions in order to implement the broad goals of Agenda 21.

The context in which these actions must take place is far from propitious. Continued low growth rates, rising unemployment and instability in currency and financial markets are already turning public and policy-making attention in the North away from issues of sustainable development and more toward short-term domestic economic management. These same forces have resulted in dramatic cut-backs in aid appropriations only a few months after the Rio meeting, even from traditionally "generous" donors such as Sweden. Meanwhile, political tensions and the time required for 'learning' to implement new global environmental programmes have slowed the process of approving and implementing specific projects within the GEF and the Multilateral Ozone Fund. The dissolution of the former Soviet Union and many of its former East European allies has raised a host of new challenges for the global community: ethnic violence, the groundswell of subnational independence movements, and a continued decline in economic output and employment which promises to add many more countries to those requiring economic assistance.

There is, however, some glimmer of hope. Perhaps the greatest success of UNCED has been in sensitizing the public in both North and South to the realities of current environmental threats — and, with somewhat less success, the intimate linkage between environment and development. Despite the range of other issues facing the world community, public concern for environmental issues remains high. At the policy-making level, the aftermath of Rio has seen a widespread recognition that "business as usual" is simply insufficient, and that existing institutions must be reoriented in order to deal with the challenges of promoting sustainable development. The 1992 U.S. presidential election results underscored this desire for reform, and repudiated the decade-long view that markets alone can solve all problems, leaving no room for the state. There is also recognition that dealing with these challenges must involve the public and voluntary sector — in part reflecting lessons learned from the impressive pre-UNCED consultative process in Canada and elsewhere. And in the business community, there is a growing sense of corporate environmental responsibility, and a strong move toward the adoption of "cleaner" technologies as a means of combining environmental and economic benefits.

In the end, it is these kinds of longer-term shifts in attitudes, practices, institutions, and directions of resource use which will determine the success or failure of the world community in implementing Agenda 21.

This is certainly true with respect to debates over "environmentally sound" technologies. As has been argued throughout this report, we need to move beyond an essentially static view of technology, in which technological advances are seen as either the root of environmental degradation or a panacea to be applied universally. Instead — and as writers such as Barry Commoner recognized two decades ago — we need to focus upon the **process** of technological change, and attempt to guide this process in the direction of greater environmental and social sustainability.

Doing this will require attention to social, political, structural and economic issues as well as technological ones. It will demand a conscious effort not only to support technological innovation, but also to promote social innovation. Only through the creative balancing of the roles and responsibilities of the state, business and civil society will we succeed in re-orienting technology to the service of environment and development.

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