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Global environment and the changing nature of states: The role of energy

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Life on earth has shown a surprising resilience in withstanding changes in the environment, and humanity in particular has adapted well to changing climate after the last glaciation some 10,000 years ago when most of the northern hemisphere was covered by ice and snow. However, all the natural changes in our environment, except natural disasters, occurred slowly over long periods of time, typically centuries.

After the industrial revolution at the end of the eighteenth century, and particularly in the twentieth century, anthropogenic aggression to the environment has become more important due to population growth in developing countries and the enormous increase in personal consumption, mainly in the industrialized countries. What characterizes these environmental changes caused by man is that they took place in a short period of time, typically decades. As result, many new problems in the environmental area, mainly those indicated in Table 4.1, have become the object of study and great concern.

Broadly speaking all these problems have a multitude of causes, such as population increase, and the growth and changing patterns of industry, transportation, agriculture, and even tourism. The way energy is produced and used, however, is at the root of many of these causes.

For example, air pollution and acid rain are largely due to the burning of fossil fuels and urban transportation. Greenhouse warming and climate change are also due mainly to the burning of fossil fuels. Deforestation

Table 4.1 Main environmental problems

Environmental problem	Main source of problem	Main social group affected
Urban air pollution	Energy (industry and transportation)	Urban population
Indoor air pollution	Energy (cooking)	Rural poor
Acid rain	Energy (fossil fuel burning)	All
Ozone depletion	Industry	All
Greenhouse warming and climate change	Energy (fossil fuel burning)	All
Availability and quality of fresh water	Population increase, agriculture	All
Coastal and marine degradation	Transportation and energy	All
Deforestation and desertification	Population increase, agriculture, energy	Rural poor
Toxic chemicals and hazardous wastes	Industry and nuclear energy	All

and land degradation are due, in part, to the use of fuelwood for cooking. Such problems are also an important cause of the loss of biodiversity.

In some other environmental problems, energy does not play a dominant role but nevertheless is important in an indirect way, as in coastal and marine degradation which is due in part to oil spills. In the case of environmental hazards and disasters, the role of nuclear energy is paramount, as clearly demonstrated by the Chernobyl nuclear accident.

Why are these problems important today and not 100 years ago? The answer to that question in the words of the great Russian geochemist, V. I. Vernadsky, in 1929 is:

> Man has become a large-scale geological force. The chemical face of our planet, the biosphere, is being sharply and consciously changed by man; even greater changes are happening unconsciously (Skinner 1994).

There are 6 billion people on the earth and their average consumption rate of mineral resources in 1994 was about 8 tonnes per capita, giving a total consumption of 44 billion tonnes a year. A century ago consumption was less than 2 tonnes/capita and population was four times smaller. So total consumption was 16 times smaller. These totals do not include all the material moved in order to facilitate mining, the soil disturbed during house building and parking-lot construction, nor any other disruptions to the crust. It is material dug out and used, directly or indirectly, to feed, clothe, transport, heat, cool, and entertain us. It is material humans dig up, move, process, use, and eventually put down somewhere else (Skinner 1994). Fossil fuels represent an appreciable part of that.

Annual mineral consumption can be contrasted with the mass of sediment transported to the sea by all rivers of the world. Suspended sediment is estimated to be about 14 billion tonnes per year and the dissolved load is about 2.5 billion tonnes, giving a total of 16.5 billion tonnes (Milliman and Meade 1983). This is only one-third of the total mass of mineral resources consumed.

Energy sources (coal, oil, gas, hydro, etc.) are distributed around the globe in a fashion that is frequently not matched to the location of the consumption centres. Access and distribution to most of them creates numerous problems such as global insecurity, of which the volatile political situation of the Middle East is an example. Other global problems are those originating in the use of nuclear energy for electricity generation, which creates the risk of nuclear weapons' proliferation.

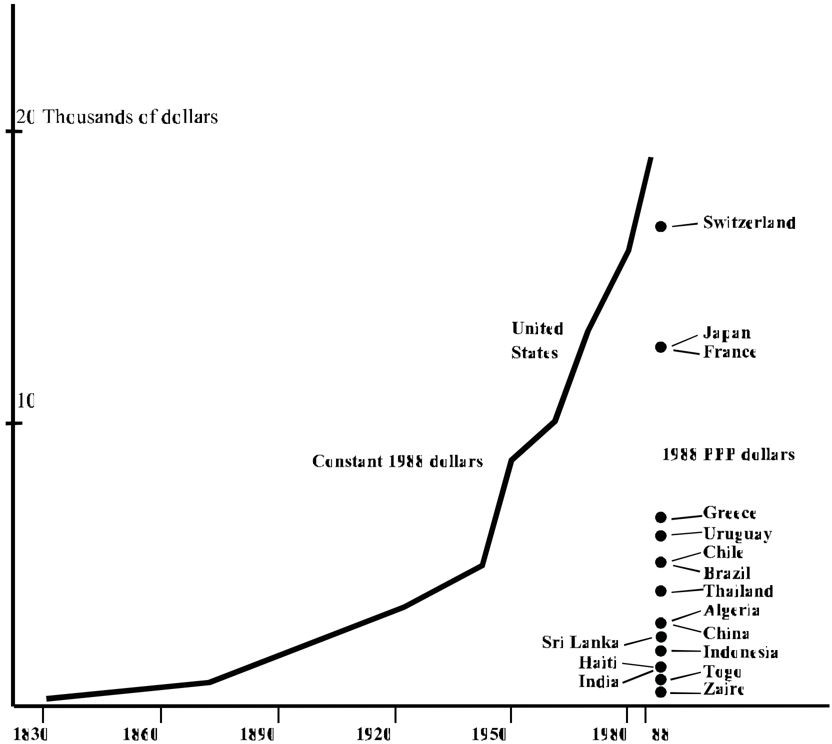
Conventional wisdom says that economic growth is roughly proportional to the growth in consumption of raw materials and energy, and the resulting pollution. The empirical evidence for such correlation is in general based on studies over limited intervals of time. If such proportionality was to last for many decades the consequences would be disastrous, because the economies of a number of very populous developing countries are growing, as well as GDP per capita, and will soon approach the level of the developed countries. This would result in great strains in the access to raw materials and energy, as well as an increase in environmental degradation.

In the low-income economies of the developing world GDP per capita is at least 10 times smaller than in the OECD (Organization for Economic Cooperation and Development) countries, and consumption of raw materials and energy is also approximately 10 times smaller. Presently one-fifth of the world's population, in the OECD countries, has reached a standard of living that can be considered acceptable. Of the remaining four-fifths – spread out in more than 100 countries – only a small fraction of the population has reached a reasonable standard of living, with the remainder standing at a level little above absolute poverty.

Figure 4.1 shows the evolution of per capita income in the period 1830–1988 for the United States as well as a number of other countries in 1988 in US dollars corrected for parity purchase power. It is clear from this figure that some countries (such as Zaire) have a per capita income lower than the United States at the beginning of the nineteenth century. Brazil is at a stage corresponding to the United States in 1950.

Such disparities in income will not last forever.

The environmental consequences of industrial development and associated energy consumption in developing countries are beginning to



Note: Countries were selected on the basis of data availability

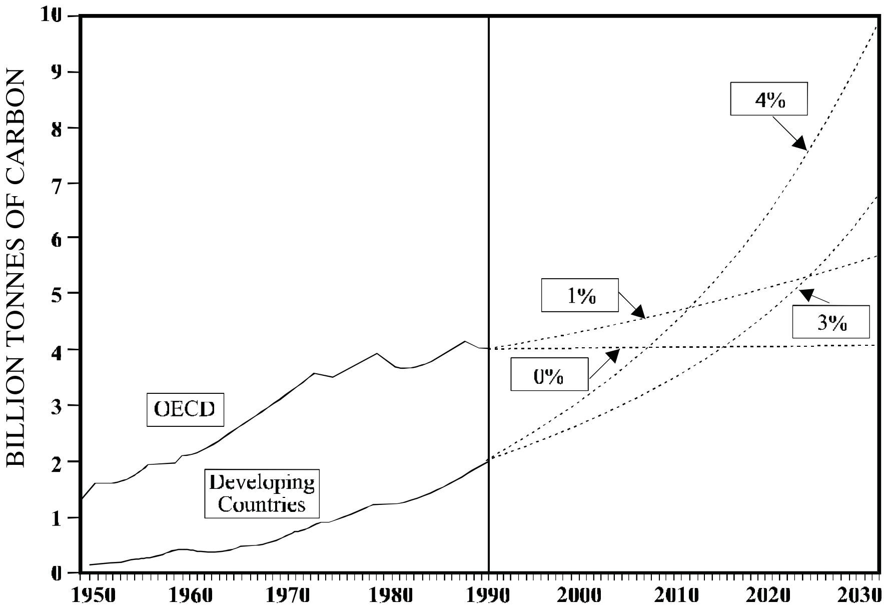
Based on data from World Bank 1991.

Figure 4.1. Per capita income: Selected countries in 1988 compared with the United States, 1830–1988

reach such proportions that they not only threaten the local population but represent a sizeable contribution to global climate change, mainly due to increased fossil fuel consumption.

As an example one can point out that, as far as carbon emissions are concerned, the emissions of industrialized countries levelled off at a rate of approximately 4 gigatonnes per year in 1980, growing at a rate of 1 per cent per year or less, while emissions in the developing countries have been growing at approximately 4 per cent per year or more (see Figure 4.2). If such trends are to continue, carbon emissions from this part of the world will surpass the emissions of industrialized countries around the year 2010.

To attenuate such problems one can introduce more rationality in the use of fossil fuels or search for carbon-free sources. This is indeed what



Based on data from Boden et al. 1993.

Figure 4.2. Carbon emissions, 1950–2030

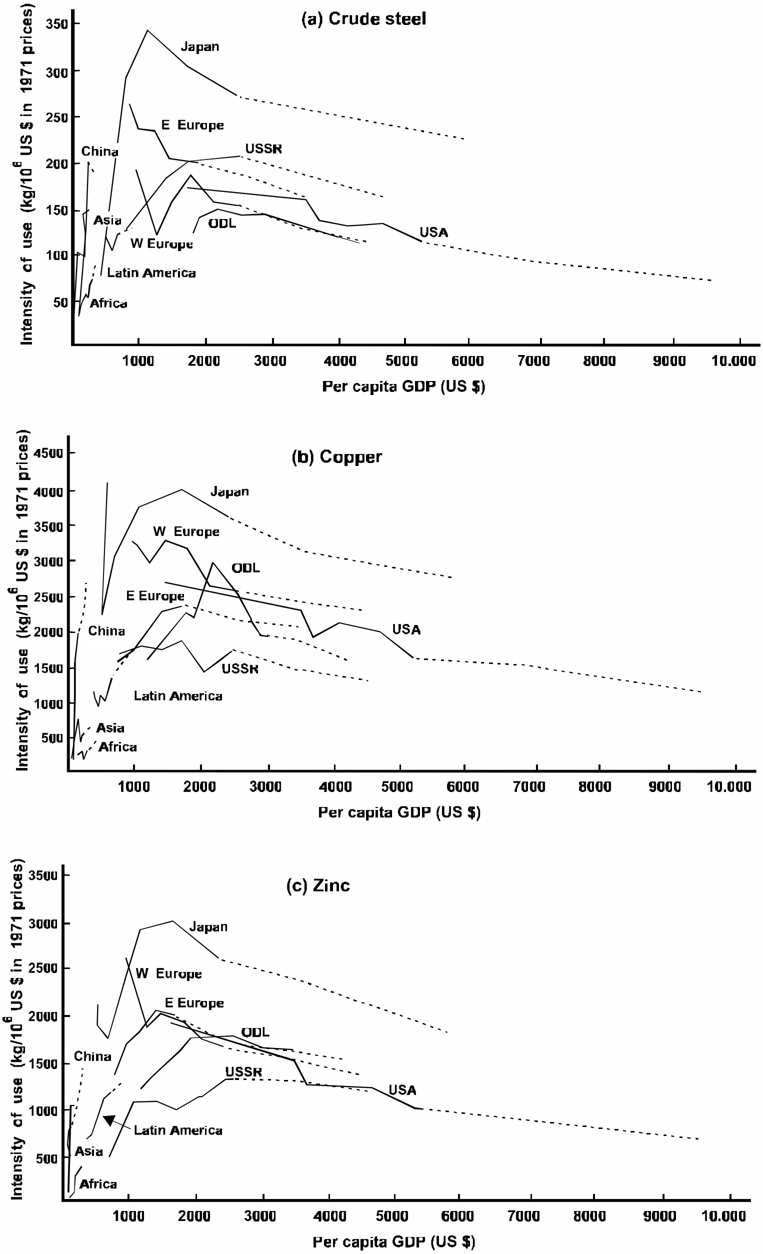
happened after the "oil crisis" of the 1970s in the industrialized countries. In order to reduce their dependence on oil imports these countries made significant efforts to rationalize their productive systems and succeeded effectively in "decoupling" economic growth from energy consumption. Such efforts were duplicated in many other areas, with the result that there is a "dematerialization" trend in the world economy in the sense that more was achieved with a reduced consumption of raw materials.

Dematerialization is a general characteristic of industrialized countries as they reach higher income. The determinants of such dematerialization are:

- changes in the structure of final demand;
- technological innovations; and
- efficiency improvements in the use of materials and substitution by alternative materials.

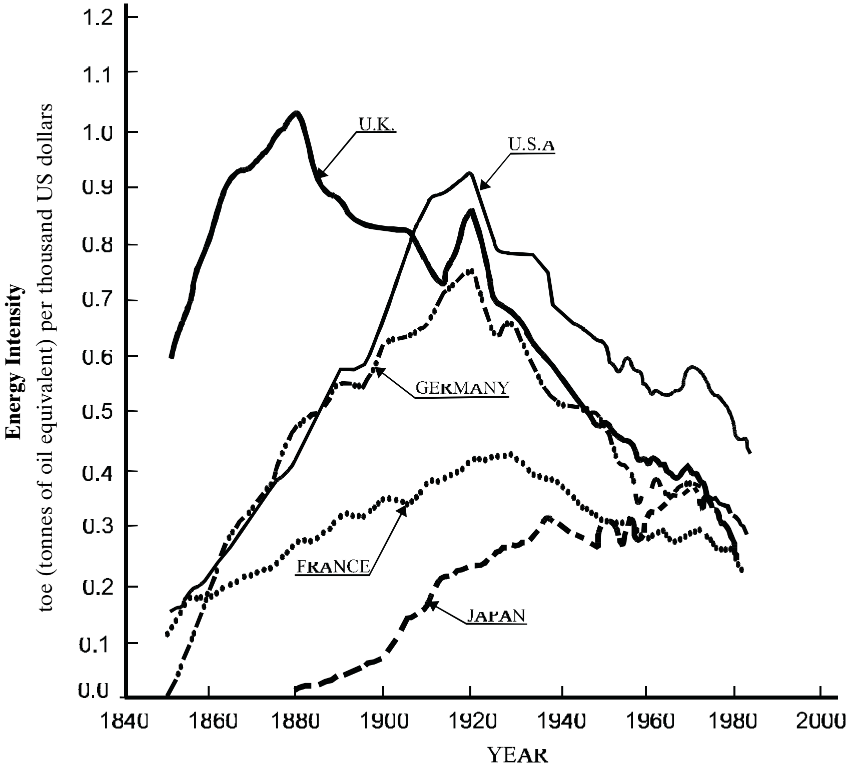
Long-terms series studies of the intensity-of-use curves (in kilograms per unit of GDP) have demonstrated that in general they have a bell shape, as shown in Figure 4.3 for the United States and other countries (Malenbaum 1978).

What one learns from those curves is that the intensity of use of a given



Source: Malenbaum 1978.

Figure 4.3. Long-term trends in the intensity of use of materials and energy



Source: Martin 1988.

Figure 4.4. Energy intensity of industrialized countries

material follows the same pattern for all economies, increasing with per capita GDP at first, reaching a maximum, and eventually declining; and that the maximum intensity of use declines the later in time it is attained by a given economy.

Such behaviour is particularly striking for the "energy intensity" (energy consumption per unit of GDP) of a number of industrialized countries, as shown in Figure 4.4 where only commercial energy was included in the analysis (Martin 1988).

What the data show is that the energy intensity increases during the initial phase of development when the heavy industrial infrastructure is put in place, reaches a peak, and then decreases. Latecomers in the development process follow the same pattern as their predecessors, but with less accentuated peaks: they do not have to reach high energy intensities in the initial stages of industrialization, because they benefit from modern methods of manufacturing and more efficient systems of transportation developed by others. This was true even before the oil crisis of 1973, and rising oil prices only accelerated the pace of structural changes in industrialized countries. This process is generally described as ''technological leapfrogging,'' in which a number of stages of choices made by industrialized countries in the past are skipped by the early adoption of modern technologies in the process of development, avoiding the costly retrofits that are required when investment is made in obsolete technologies.

Enlightened governments can have an enormous success in accelerating this evolution, mobilizing local resources, investing in education, and establishing the indigenous capacity to develop or choose foreign technology selectively. This was to a large extent the case in Japan after the Meijii restoration during the last decades of the nineteenth century, which in 30 years converted Japan into a world power.

What is crucial in this approach is the capacity to choose among technologies and finance preferentially projects incorporating modern technologies, or conducting the necessary research for that. The best example of this approach is the one given by Japan after the Second World War with the creation of MITI (Ministry of International Trade and Industry), which is responsible for the support of research and development plus industrial development.

There are a number of examples of technological ''leapfrogging'' occurring in the developing countries today (Goldemberg 1998). The first is the adoption of cellular telephones to supplement, and sometimes replace completely, obsolete traditional telephone systems (which require extensive wiring) in cities such as Manila and some regions in China. Although cellular telephones were originally developed for mobile use or rural areas where wiring is very expensive, technical developments indicate that they can also be economically competitive for regular service.

A second example is the restructuring of the world steel industry, which is in a period of change, opening new possibilities for developing countries to enhance their comparative advantages. In the past five years large conventional, centralized, and integrated steels mills, which require the use of large blast furnaces, coke ovens, and sintering plants, have come under attack for their negative environmental impacts, including the production of toxic and carcinogenic by-products. In many parts of Europe, licences for new plant construction are impossible to obtain. Where plants are in operation, taxes are often applied. For example, an ''ecotax'' of US$25 per tonne of produced steel is levied on a sintering plant in Oxelosund, Sweden, because of its emissions of dioxin.

One result has been an increase in the number of electric arc furnaces, which were used in 35 per cent of total steel production worldwide in 1995 compared to 10 per cent in the 1960s and 22 per cent in 1980. This technology depends on the availability of low-cost electric energy, which is abundant in many of the developing countries to which the modern steel industry is migrating. Another trend has been toward descentralized medium-sized mills (production capacity less than 1 million tonnes per year). Still another result is the rebirth of charcoal-based pig-iron and steel production in Brazil: 19 per cent of all steel in the country (4.3 million tonnes) is produced in charcoal-based steel plants in addition to 4.5 million tonnes of pig-iron.

When one concentrates attention on energy there a number of opportunities to explore, the main ones being the modernization of the use of biomass and photovoltaics.

The modernization of the use of biomass

Biomass in the form of fuelwood, agricultural residues, dung, and bagasse provides 14 per cent of the world's primary energy (equivalent to 25 million barrels of oil per day). In developing countries – where it contributes approximately 35 per cent to all energy consumed – biomass is predominantly used as a non-commercial fuel. Modernization of the use of biomass is taking place through the conversion of biomass into liquid and gaseous high-quality fuels, such as ethanol from sugar-cane and low-BTU gas for combustion.

Ethyl alcohol (ethanol) is produced from fermented sugar-cane juice on a large scale in Brazil, and used as a substitute for gasoline in automobiles. Approximately 200,000 barrels per day of alcohol are in use, reducing by 50 per cent the amount of gasoline needed for Brazil's 10 million automobiles. Ethanol is an excellent motor fuel: it has a motor octane of 90, which exceeds that of gasoline, and its use in higher compression engines (12.1 to 1 instead of 8.1 to 1) compensates for its lower caloric content.

The expansion of the sugar-cane plantations from less than 1 million hectares to 4 million hectares between 1975 and 1990, and the nearly 400 processing plants needed to produce large amounts of alcohol, have resulted in the creation of approximately 700,000 jobs. The environmental problems encountered initially in the distilleries, such as disposing of liquid effluents and bagasse, have been solved by converting the stillage into fertilizers and bagasse into a fuel for electricity generation.

In addition, the substitution of the gasoline that would otherwise be consumed avoids emissions of 9.45×10^6 tonnes of carbon per year, which corresponds to 18 per cent of all carbon emissions in Brazil.

The amount of bagasse (and other agricultural residues) remaining after ethanol production is estimated to be 4×10^6 tonnes of dry matter, a significant portion of which is being used or could be used for electricity generation. Ethanol from sugar-cane is also used in Zimbabwe, and could play an important role in Cuba and other sugar-cane-producing countries.

Burning fuelwood, bagasse, and other agricultural residues to produce steam and generate electricity is a well-known technology in use in many countries. In the United States some 8,000 MW of electricity are generated per year. Present systems frequently use low-pressure boilers and their efficiency is usually below 10 per cent. The simplest improvement possible is to use condensing-extraction steam turbines (CESTs) and higher pressures. Efficiencies of up to 20 per cent can be reached this way.

Advanced technologies have been proposed to convert solid biomass into a low-BTU gas through gasification and use this gas to power gas turbines. Efficiencies higher than 45 per cent can be expected from a biomass integrated gasifier/gas turbine (BIG/GT) system. The merit of BIG/GT systems would be the ability to provide such high efficiencies in small units, in the range suitable for economical use of biomass (20–100 MW).

In a project in progress in Brazil for a 25 MW demonstration plant – with the financial support of the Global Environment Facility (GEF) – General Electric has adapted their aeroderivative turbines for the low-BTU gas to be used and TPS Termiska Processer AB, a Swedish company, has developed air pressure gasifiers. Once developed and fully tested the technology could be used worldwide. Producing fuelwood in large ‘‘energy farms’’ will be particularly significant to provide a basis for rural development and employment in developing countries.

This is a case in which multinational companies have developed the necessary technologies for use in a developing country, thus opening a market for their products. It is an example of a ‘‘leapfrogging’’ activity where international donors plus multinational companies join forces in stimulating development in a developing country. In the pilot plant being built in Brazil with a World Bank loan, Shell Brazil and local electricity companies are shareholders.

Photovoltaics

Photovoltaics (PV) technology could play an important role in tropical areas – where most of the developing countries are located – not only in decentralized but also in centralized units feeding directly into existing electricity distribution grids. While PV technology is perhaps the most inherently attractive of the renewable technologies it is also – due to its cost – the farthest from being commercial.

Estimates suggest that 2 billion people are without access to modern electricity, many of whom are willing to pay the full cost for the services it can provide. With suitable delivery systems, it is estimated that it may be possible to reach up to 50 per cent of the rural population with PV. In addition, wind for electricity production is also an attractive option.

All these new technologies have reached technological maturity – although new improvements are bound to take place – but suffer from the usual problem of initial high cost which is typical of new technologies.

Usually prices of any given manufactured products decline as sales increase according to "experience curves" (or "learning curves"), which reflect gains due to technological progress, economies of scale, and organizational learning. Experience shows that such decline is exponential as cumulative production grows. An indicator called progress ratio (PR) is often used to describe it. For example, a PR of 80 per cent means that the cost declines 20 per cent for each doubling of production. The lower the PR the faster the decline in cost.

Figure 4.5 shows the distribution of the PR observed for more than 100 industries, which indicates a cluster around a PR of 80 per cent (Dutton and Thomas 1984).

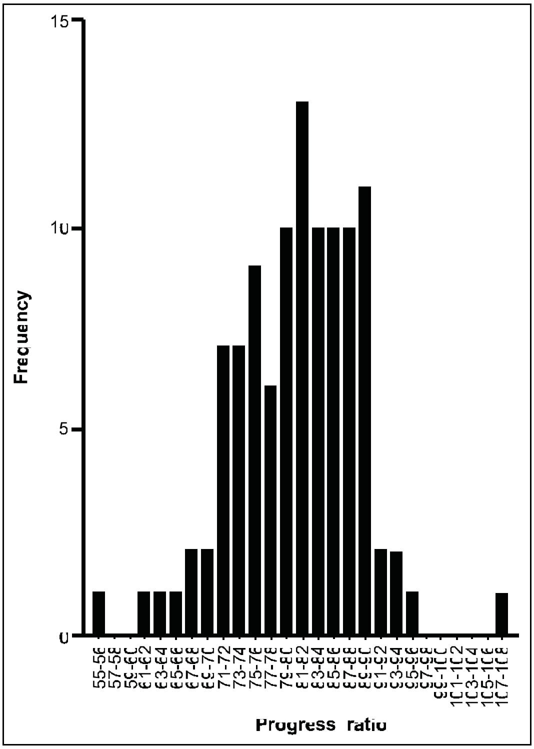
For photovoltaics costs are falling, as indicated in Figure 4.6, which corresponds to a learning curve with a PR of 81.6 per cent.

Aggregation of large international markets for PV sales in developing countries could be a mechanism for accelerating the rate of price reduction for PV systems produced in industrialized countries. Costs could be brought down quickly via mass purchases that could be facilitated by various national and international organizations, in conjunction with increased research and development.

What can governments do?

What can governments do to promote the adoption of better technologies and "technological leapfrogging"? To answer this question it must be realized that such problems fall into three distinct categories and the authorities responsible for solving them are different in each case: local, regional, or global.

Local pollution has to do with local governments since it deals with clean air, fresh supplies of clean water, the removal and disposal of solid wastes and liquid effluents, street cleaning, etc. This is what has characterized "good" small and medium-sized cities since Roman times. Yet in many developing countries a large fraction of the population lives among the rubble and residues it produces, due to the lack of resources to remove waste and build sewers and the engineering works needed for the

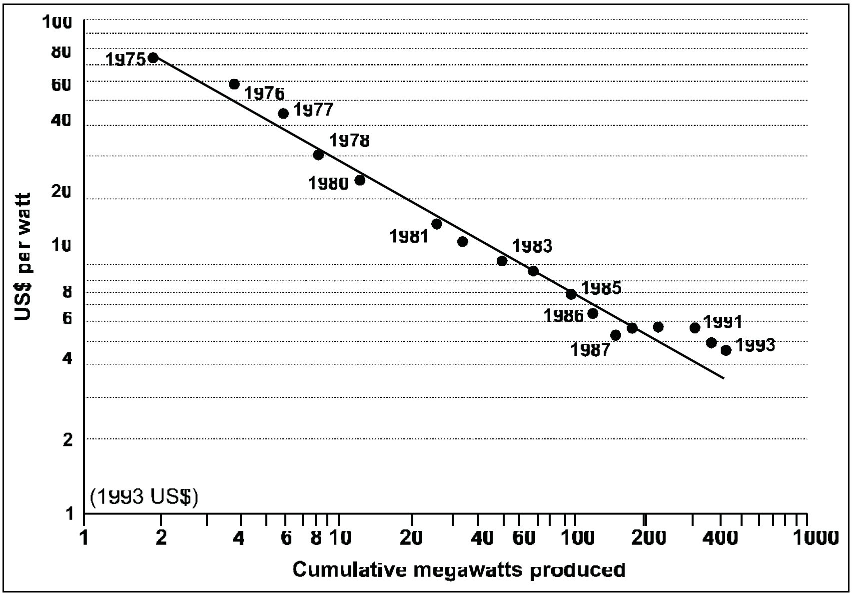


Source: Dutton and Thomas 1984.

Figure 4.5. Frequency distribution of the progress ratio

supply of water. This is quite evident in the slums of the big cities, which generally speaking surround ‘‘islands of prosperity’’ where the well-to-do succeed in reaching a quality of life that is comparable to that of Europe or the United States. Local pollution goes together with poverty.

Regional pollution is caused mainly by automobiles, energy production, and heavy industry, which are characteristic of more prosperous societies. Large cities and adjoining areas, such as Los Angeles, Mexico City, and São Paulo, have been ‘‘suffocating’’ under the pollution caused by the emissions and ‘‘smog’’ resulting from burning fossil fuels. Sometimes the amount of pollution produced is large enough to cause regional and even transborder problems, such as the acid rain that originates in the United States but is responsible for the destruction of life in Canadian lakes. The same happened to lakes in Scandinavia, due to industrial activities on the other side of the Baltic Sea. Regional pollution has to be



Source: Flavin and Lenssen 1994.

Figure 4.6. Penetration curve for photovoltaics

dealt with at the state or national level, and eventually among a number of countries.

The third category is global pollution, and its most obvious consequences to date are the destruction of the stratospheric ozone layer by CFCs and the "greenhouse effect." These problems result from changes in the composition of the atmosphere and have little to do with national borders. The causes of such global problems are gases originating anywhere in the world and are such that, for example, the well-being of people living in Switzerland might ultimately be affected by what takes place in India or China (and vice versa). Global pollution can only be tackled at the international level.

When dealing with local and regional pollution, governments can introduce incentives to stimulate better practices and guide markets; one of the most interesting methods for doing this is the one introduced in the United Kingdom, where it was decided that utilities should incorporate a minimum amount of renewable energy capacity into their portfolios even if they have less expensive alternative means of providing power.

The United Kingdom adopted the renewables' Non-Fossil Fuel Obligation (NFFO) in 1989 after privatization of the electric power sector. It evolved from the need to find a means of supporting nuclear power after it was realized that nuclear power could not survive privatization without subsidies. The British government was required to obtain a subsidy permission from the European Commission to levy a tax on electricity in order to do it. The government asked instead for permission for a levy on fossil-based electricity to support non-fossil-based electricity in an NFFO – a request that was granted by the Commission. The NFFO thus came to be understood to include both renewable and nuclear energy (Mitchell 1995).

There are other variations of such mechanisms (see Reddy, Williams, and Johansson 1997), one of which is the adoption of caps on emissions of pollutants such as was done for SO_2 in the United States; once they are established at a national level the agencies in charge, such as the US Environmental Protection Agency (EPA), can issue emission permits that are tradable and that encourage technological development of processes that avoid SO_2 emissions.

Dealing with global environmental problems is, however, the great challenge of our day: it requires international "hard" laws, such as setting mandatory targets and timetables for the reduction of emissions of the undesirable gases which will force technological change in the desired direction. In the case of CFCs, the Montreal Protocol was successful in doing that, but the same success was not achieved in the case of other "greenhouse gases" such as carbon dioxide (CO_2), methane (CH_4), and others. The UN Framework Convention on Climate Change (UNFCCC) adopted in Rio in 1992 can be clearly categorized as an international "soft law."

Industrialized countries announced in Rio their decision to reduce CO_2 emissions to 1990 levels by the year 2000, but that was not a binding commitment and nor will it be fulfilled. Actually emissions are growing in most of these countries. On the other hand, developing countries accepted no limitations on their future emissions since this could – in their perception – hurt their development goals.

In successive meetings of the Conference of the Parties (COP) of the UNFCCC, efforts were made to convert the Convention into a "hard law," the idea being that industrialized countries would stabilize emissions at the 1990 level and eventually reduce them by 5–15 per cent by the year 2010. Proposals to have developing countries accept binding or voluntary targets have also been made, mainly by the United States. Agreement was finally reached in December 1997 when COP-3 adopted the Kyoto Protocol, which contains the following key elements.

- A global Annex I target of 5.2 per cent emission reduction in the first five-year period, to run 2008–2012.

Table 4.2 Total energy consumption (GTOE)

Year	Scenario	Primary energy	Renewables
1990		8.8	0.32
2010	OECD/IEA*	11.59	<0.6 (<5%)
2020	WEC (ecologically driven)	11.3	3.4 (30%)
2025	RIGES	11.2	5.0 (45%)

Sources: OECD/IEA – IEA/OECD 1994; WEC – WEC 1993; RIGES – Johansson et al. 1992.
* Does not include non-commercial fuels such as wood or animal waste

- Coverage of six gases (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6).
- Comprehensive coverage of sources and sinks.
- Annex I emission trading allowed.
- A clean development mechanism (CDM) that allows non-Annex I Parties to benefit from project activities resulting in certified emission reductions, while Annex I Parties can use these certificates to contribute to compliance.

As in the case of SO_2, the acceptance of caps on emissions will stimulate efforts to find alternative technologies to produce energy from carbon-free energy sources, such as renewable ones like wind, photovoltaics, biomass, hydrogen, etc. Estimates have been made of the possible role such sources could play early in the twenty-first century; one of the outstanding projections is that made by the World Energy Council in an "ecological-driven scenario" which predicts that by the year 2020 some 30 per cent of the total primary energy consumed could be renewable as compared to 3 per cent in 1990 (see Table 4.2).

There are significant technical opportunities to steer the present-day energy system, mainly based on the use of fossil fuel, to less carbon-dependent primary sources of energy (renewables) and more efficient energy use.

However, the obstacles to "technological leapfrogging" are considerable, since there are entrenched interests in industrialized countries which profit from supplying conventional technologies based on fossil fuel use to developing countries. Such interests have important allies in the international financial institutions, such as the World Bank, which are "colour-blind" regarding the technology involved in their loans and show no preference for innovations, which in general they consider very risky. Coupled with that is the passivity of governments which allow the import of machinery and even factories without any concern for their acceptability on environmental grounds. Enlightened governments and stricter criteria for funding in the World Bank and similar financing institutions could change that situation drastically.

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