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Economics and the Environment: A Survey of Issues and Policy Options

Jon Nicolaisen,

Peter Hoeller

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Concerns over the pace, scope and causes of environmental degradation have led to a renewed interest in the way environmental and economic policies interact. This paper first reviews the main causes for excessive use of environmental resources in a market economy, and how governments may conduct policies to counter environmental degradation. The focus of the paper then shifts towards the implications of economic growth on overall wealth and the possibilities for preserving or expanding the basis of this wealth, particularly in relation to the notion of sustainable development. Finally, it examines policy options for limiting global environmental problems such as climate change, in particular as regards the trade-offs involved in curbing the use of fossil fuels.

* * * * *

Les inquiétudes concernant le rythme, l'étendue et les causes de la dégradation de l'environnement suscitent un intérêt renouvelé pour la façon dont les politiques environnementales et économiques interagissent. Dans un premier temps cette étude examine les principales causes de l'utilisation excessive des ressources de l'environnement dans une économie de marché et la façon dont les gouvernements peuvent mener des politiques pour contrecarrer la dégradation de l'environnement. Dans un deuxième temps, elle s'intéresse aux implications de la croissance économique sur la richesse globale et sur les possibilités de préserver ou d'accroître les fondements de cette richesse, en particulier en relation avec la notion de développement soutenable. La dernière partie porte sur les options politiques visant à limiter les problèmes globaux d'environnement tel que le changement climatique, en particulier en ce qui concerne les trade-offs qu'implique la maîtrise de l'utilisation des combustibles fossiles.

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I. INTRODUCTION AND SUMMARY

This paper addresses two issues: how economic considerations should be given due weight in environmental policy-making and how environmental considerations could be better integrated in economic policy decisions.

The intensified interest in the environment in economic policy discussions can be attributed to several related factors:

-- a growing awareness that environmental problems have important economic dimensions that must be brought to the forefront if the most desirable outcomes are to be achieved;

-- the recognition that charges and other economic instruments, which have important macroeconomic effects, are likely to have a key role in this process;

-- the transborder nature of many environmental problems which accentuates the constraints and requirements of international policy co-operation; and

-- the recognition of a global dimension to environmental problems: concerns about the effects of certain emissions on the ozone layer and global climate are the two most notable examples and have provided the catalyst for new debate.

While the consequences of increasing global scarcity of natural resources were much debated in the 1960s and 1970s, few now accept the view that the world economy is moving towards a resource crisis. Concerns persist, but have shifted towards issues such as degradation of the atmosphere, ground water and oceans. There is an important economic dimension to such environmental problems for two basic reasons:

i) the divergence of the private costs of an activity from its social costs, which characterises the use and hence misuse of many environmental resources such as air and water, means that the desired trade-off between environmental amenity and the production of marketable goods is not achieved under laissez-faire; and

ii) there are links between economic growth and the environment, since environmental policies and developments increasingly have significant overall repercussions and because the pace and structure of economic growth impinges on the environment; furthermore, market failures or distortions not directly related to the use of environmental resources may lead to sub-optimal environmental outcomes, for example, when road congestion in urban areas boosts the exhaust emissions associated with a given amount of travel.

The first main section of the paper is restricted to the issue of market failure and deals with the traditional, largely microeconomic aspects of such problems (Section II). The following section deals with the links between economic growth and the environment (Section III). The concluding section then addresses the current policy issues, focusing in particular on those with an international dimension (Section IV). Due to its potential consequences for both environmental and economic policies, particular attention is given to the climate change issue. The remainder of this section summarises the main points of the paper.

Externalities. A major cause of environmental degradation is the presence of external environmental costs (Section II). Open access to many environmental resources, which are regarded as common property by individual market agents and governments, means that these agents lack incentives to take the full costs of environmental degradation into account. Such costs will tend to increase over time as resources are degraded or depleted and thus become scarcer.

Policy instruments. The proper policy response to such problems is to internalise the cost of pollution. Regulatory approaches have generally been preferred to date, and have in some cases been relatively successful in reducing pollution. However, expanding the use of general economic instruments could increase overall efficiency and this will become an even more important consideration to the extent that the scale of response to environmental problems increases. The relative efficiency of different policy instruments will depend on specific considerations such as the geographical extent of the problem, the number of pollution sources, whether monitoring is easy, transaction costs and whether the sector is subject to other market distortions.

Sustainable growth. Economic growth is influenced by the relative scarcity of environmental resources, as the environment is used for the extraction of material inputs and the disposal of residuals (Section III). Establishing a meaningful definition of sustainable growth is a first step in analysing the interactions between the environment and economic growth. It is conceivable that the degradation of particular environmental resources, such as the continuous build-up of greenhouse gases or the degradation of the ozone layer, might significantly reduce future consumption potential, broadly defined. Moreover, the external costs of pollution may have to be eliminated, or at least reduced, in the long run if sustainable growth is to be achieved. On the other hand, measures taken to reduce environmental degradation may entail costs in terms of foregone production and consumption. There is thus a cost-benefit trade-off that needs to be clarified with estimates of abatement and damage costs.

Public choices. The actual choice between alternative trade-offs may become manifest through various political processes. Sustainable growth paths could be operationalised as reaching a decision on a set of objectives -- defined in terms of costs to be incurred or quantity reductions to be achieved -- and implementing the chosen objectives through policy instruments consistent with this decision. In essence, this strategy would boil down to one of reducing externalities -- the message of Section II. Indicators of the discrepancy between actual developments and policy objectives are required in order to monitor successes or failures and hence to adjust policy as necessary.

Sequencing of policy. Since the potential risks involved in the degradation of environmental resources are largely unknown, and will remain unknown in the foreseeable future, a strategy to cope with uncertainty and environmental risks will be an important policy element (Section IV). The risk problem that has to be considered concerns the robustness and sequencing of policies. If some pre-emptive measures were to be carried out, it would be sensible to start with the cheapest and most cost-effective measures. For example, while it would seem that the shadow cost implied in stabilising the concentration of greenhouse gases could be substantial, there is considerable scope for reducing emissions of the most "efficient" greenhouse gas, CFCs, together with some substitution away from CO_2 emissions, at relatively low cost. Thus, a first step could be to investigate whether some environmental measures could serve to improve general economic efficiency, while at the same time increasing future options and flexibility. Such policies could include environmental tax reform, a changing of tax rates across fuels to better reflect their relative pollution intensities, and a reduction of subsidies that significantly increase pollution by distorting market incentives.

International co-operation. The evidence suggesting that global environmental threats will cause substantial and irreversible damage seems so far to be inconclusive. However, while it would seem necessary to be prudent, there is no reason to neglect the possibility of significant future environmental damage. Appropriate and carefully prepared measures to curb global environmental pressures could thus be justified. Although there are obvious difficulties in setting up credible international agreements, policy responses in this domain will involve international co-operation if they are to be effective. One possibility could be to proceed in steps, identifying and implementing the least-cost and most clearly-agreed policies, and moving to more ambitious proposals as evidence and international consensus become clearer. A feature dominating environmental agreements to date is that they have involved equi-proportional targets for signatories. In general, a less costly solution would be to let emission reductions vary according to abatement costs.

II. THE ECONOMIC DIMENSION OF ENVIRONMENTAL PROBLEMS

A. Environmental externalities

The extraction or processing of raw materials and the consumption of goods often carries with it external environmental costs. Externalities arise because of the non-excludable nature of environmental goods. As no property rights are assigned to these resources, the environment is, in this respect, a public good. Herfindahl and Kneese (1974) state that water and air pollution, for example, occur because air and water are assets held in common, but with open access to depletion. In a market economy, unless private market agents own the affected recipients, external costs will not be internalised and there will tend to be "excessive" environmental degradation. Some environmental problems may, therefore, be resolved by defining property rights (see e.g. Coase, 1960).

If polluters are not liable for the full cost of environmental damage to others, pollution will be above the social optimum. Marginal damage could increase abruptly if there are threshold effects in the chemical and biological processes at work or within the ecosystem as a whole. For example, soils will have a certain absorption potential for acid rain, as acids are at first easily accumulated and may actually add nutrients to lime-type soils. If acidification continues, however, this might trigger damage to forest and soil as the acidity level exceeds natural toleration thresholds.

The abatement cost function illustrated in Chart A shows the marginal cost of preventing pollution. For most pollutants, marginal abatement costs typically increase with the amount of emissions abated. The optimal point of emissions is where the incremental cost of additional abatement just outweighs the gains from reduced emissions. This is the intersection point A in Chart A. Any marginal cost of abatement less than the optimum (such as point B) will lead to a level of emissions which is greater than the optimum (point C), with external costs amounting to DE not being internalised. Quantification of this sort of analysis is being carried out on a regular basis by the United States Environmental Protection Agency, and to some extent by other governments. It has also been attempted by Nordhaus (1990) for the case of climate change. As discussed in Section III, it is, however, not easy to derive robust estimates of both damage and abatement costs so that establishing an optimum policy is usually difficult in practice.

There are both spatial and intertemporal dimensions of the externalities issue which need to be considered in judging how externalities should best be treated. The spatial dimension is important because the geographical diffusion of external costs, and hence the optimal choice of policy instruments, varies according to specific geographical conditions. For instance, the impact of sulphur emissions may vary with soil quality in the immediate surroundings of the emission source, as well as with the amount transported long distances by weather systems. If sulphur is deposited on lime-type soils, the damage may be negligible, while it can be severe in more sensitive soils. This is an important issue for both air and water pollution (see box overleaf) but is also important in the case of wastes, particularly in densely populated and industrial areas.

The two most notable global issues are the depletion of the ozone layer and the effect of "greenhouse gases". The stratospheric ozone layer may have been reduced through a chemical process linked to emissions of chlorofluorocarbons (CFCs) and halons, apparently reducing the protection of the Earth's surface from ultraviolet rays (Table 2) (1). This has lead to international agreements to reduce the use of CFCs. Increases in the concentration of greenhouse gases may result in global warming of the lower atmosphere that could lead to a rise in the sea level and to climate changes such as changes in rainfall patterns (see the later discussion and box in Section IV).

The intertemporal dimension assumes important proportions when damage arises from the build-up of pollutant stocks as well as from pollution flows. Some pollution issues may be regarded as strictly a problem of flows, as the substance in question will disintegrate or dissolve relatively quickly without any further damage to the environment. In many cases, however, pollutants accumulate in the atmosphere or in the soil, and it is the cumulative effect of

AIR POLLUTION

1. Emissions of substances to the air are in general dominated by natural processes; what is released into the atmosphere by human activity often consists of substances that are also emitted by natural processes such as plant decay or volcanic activity. Before human activities contributed substantially to emissions, natural systems evolved so that emissions and uptakes of compounds in ecological cycles were roughly in balance. Human activities have altered these cycles much more quickly than the natural systems can adapt through evolution. What we call air pollution are emissions which can be proven or suspected to imply substantial damage either directly to human welfare or indirectly through damage to our natural environment. The latter may vary greatly depending on local weather conditions, soil composition (e.g. acidification) and the ability of renewable environmental resources to regenerate.

2. Local air pollution in densely populated areas is largely responsible for most direct adverse health effects (see Table 1). The adverse effects of traditional air pollutants have been known for many years; and emissions of some pollutants have been cut back successfully, action against smog in London in the 1950s being an early example. Another example is the local or regional formation of photochemical oxidants and their effects on health and vegetation. The effects of photochemical air pollution -- eye irritation, plant damage and visible smog (see e.g. OECD, 1979) -- first became manifest in the 1940s in the Los Angeles basin.

3. The acid rain problem is an important transborder problem in both Europe and North America The main air pollutants causing acid rain are sulphur and nitrogen oxides that undergo chemical transformations in the atmosphere, forming acids and acid salts which may then be transported through the atmosphere. Policy action often co-ordinated by international agreements, resulted in sharp reductions of SOx emissions since the 1970s. Progress in reducing NOx emissions was slower in many countries (Chart B).

WATER RESOURCES

1. Water resource issues have been, over a long period of time, concerned mainly with quantitative matters: having enough water for household use and for agriculture. In some OECD countries (such as Australia, Spain and Turkey), this concern is still of prime importance. In the last few decades, however, emphasis has shifted from quantitative to qualitative water resource management. Water pollution abatement is responsible for about half of all pollution abatement expenditure (Table 5).

2. Sources of water pollution can be divided into three categories:

- <u>municipal sewage</u> or waste water is a major source of water pollution containing suspended solids, nutrients, heavy metals and bacteria that can cause disease;

- <u>industrial waste water</u> is discharged into waterways and can contain persistent organic matter, cyanide, acids, alkali material, and heavy metals. The major polluting industrial groups are: pulp and paper, alkali, petroleum refining, fuel processing, chemicals, metal finishing and metal mining;

- <u>non-point pollution sources</u> from land-based activities such as agriculture (through intensive use of fertilisers and pesticides), forestry, urban drainage, transportation, construction and sanitary landfill have become significant. For example, Chart C shows a rising trend in use of nitrogenous fertilisers in all OECD countries over the past two decades, with the Netherlands and Denmark being the most intensive users.

3. Progress has been made in many countries, particularly with pollutants that have been the object of control measures for more than a decade, such as organic oxygen-consuming substances, certain micro-organisms and some heavy metals like mercury or cadmium. Chart D shows a counter-example of rising nitrate levels in Danish groundwater.

pollutant stocks that has an environmental impact. Hence, flow problems can become stock problems: while nature for some time may seem to tolerate a certain flow of pollutants without any visible environmental impact, environmental degradation may accelerate beyond certain thresholds. Stock-flow relationships thus imply the presence of potentially large intertemporal externalities.

Such intertemporal user costs -- or scarcity rents -- of pollution represent the social opportunity costs of polluting today at the expense of tomorrow's environmental quality. Generally speaking, the more environmental quality is degraded, the scarcer it is, and the higher are user costs (Howe, 1979; and Herfindahl and Kneese, 1974). User costs of pollution will not increase over time as long as natural regeneration, for instance the cleansing of acid rain in lime-type soils, offsets pollution. But beyond thresholds determined by natural regeneration, environmental quality will decrease and user costs increase. The external costs of pollution may therefore increase at the margin as pollutants are accumulated in natural recipients. As long as environmental quality is unpriced or undervalued, the magnitude of these externalities will thus tend to increase over time (Pearce, 1989). If damage costs can be shown to be significant, continued degradation of environmental quality, if unchecked, presents a prima facie case for government intervention.

B. Market failure, potential solutions and policy to date

In the first half of this century, Pigou and other economists recognised externalities as a source of market failure and suggested the use of fiscal instruments for internalising external costs. Since then, a substantial literature has accumulated concerning environmental externalities, various forms of related market and government failure, and the policy options available to deal with them (2).

In the early 1970s the OECD formulated the Polluter Pays Principle. As defined by the OECD, this states that the polluter should bear the cost of measures to reduce pollution decided upon by public authorities (OECD, 1986). Contrary to optimum principles, however, the Polluter Pays Principle does not specifically address the allocative efficiency of specific pollution control policies -- that is, the question of what the polluters should pay. For instance, if the cost of mandated abatement measures exceeds the social cost of pollution at the margin, the application of the Principle will involve an over-optimal level of pollution control expenditure. Rather, the Principle is basically a "non-subsidy principle", according to which the costs of pollution control -- not necessarily the costs of pollution -- should be paid by the polluter.

Pollution control policies have successfully reduced emissions of traditional pollutants in many OECD countries. Chart B shows trends in energy use and emissions of traditional air pollutants. Pollution intensities, as compared to energy use, were brought down for most pollutants, with the exception of NOx, for which strict control policies were not in place in many OECD countries until very recently. Similarly, traditional organic water pollution came down due to installation of water rinsing equipment, as is shown in Chart E. While pollution has been reduced across a broad range of emissions, control policies and the installation of add-on technology failed in many instances to break the link between pollution and the related polluting activities. For instance, the relative ranking of countries with respect to air pollution is closely related to overall energy intensities, as illustrated in Chart F. Even with stringent pollution control measures, the United States with its high energy intensity, maintains high pollution intensities, both measured relative to GDP and per capita.

Abatement expenditure has remained between 1 and 2 per cent of GDP in most OECD countries since the late 1970s (see Section III). Around half of total expenditure is used on water pollution abatement, while expenditure on waste management and air pollution control varies between slightly over 10 per cent and one-third of total expenditure (Table 3). The share of expenditure on air pollution control has been rising since the early 1970s, but total expenditure is still dominated by traditional public services such as water and waste management.

In considering the choice of policy instruments a distinction is usually made between various forms of direct regulations (sometimes known as the "command and control" approach) *versus* what are usually termed "economic instruments" (3). The application of economic instruments usually implies that the market mechanism is used explicitly in controlling pollution or internalising external costs. Examples of the two types of instrument are shown in the menu of instruments summarised in Table 4 and the relative advantages and disadvantages of each are discussed below. When environmental policies became more pervasive in the late 1960s and early 1970s, most OECD countries relied on regulatory controls. By contrast, economic instruments were used rather rarely, and were subject to controversy and resistance by industry, government and the general public. A comprehensive overview of pollution control measures is given in OECD (1987).

Economic instruments are rarely used as "pure" substitutes for direct regulation. Rather they have tended to be used to supplement direct regulations in mixed systems. A recent OECD survey covering 14 Member countries identified some 150 cases of various economic instruments, including 80 applications of pollution charges (Table 5) (4). The most widely used economic instruments are charges (see box overleaf). When properly designed, they should represent the shadow cost of pollution and oblige polluters to pay for the environmental services they consume, for example when they dispose of waste in a river. Such charges act as incentives by encouraging polluters to reduce discharges to the extent that it is cheaper to treat them than to incur the charge (i.e. to the level where the unit rate of the charge equals the marginal abatement cost).

The use of emission trading is an alternative to the use of pollution charges. This innovative approach was developed in the United States, mainly in air pollution control (but also lately in water pollution control). The results are promising compared with the usual approach of direct regulations alone, and are leading to substantial savings. Further application of tradeable emission allowances in the United States to reduce SO_2 emissions are estimated to cut annual abatement costs by as much as 20 per cent. Where a statutory ceiling on pollution has been reached in a given area, a polluting firm can set up or expand an activity only if its additional pollution emissions do not significantly worsen ambient quality. The firm must therefore buy "rights" to pollute from other firms, which then are required by law to abate their emissions by an amount equal to the traded emission rights. The

CHARGES

1. Effluent charges are payments on direct releases into the environment. They are often used in water pollution control (in Australia, France, Germany, Italy, Netherlands). Effluent charges are also applied in solid waste management (Australia, Belgium, Denmark, Netherlands, United States) and in the abatement of noise from aircraft (France, Germany, Japan, Netherlands, Switzerland). Implementation for these activities is eased by fixed and easily identifiable points of discharge and by applying the charges most often only to large sources of wastes. Effluent charges are chiefly used for financing individual or collective systems of pollution control. In the Netherlands, the level of charges for effluents to water are so high that they constitute a strong incentive to clean up water pollution.

2. User charges are payments for the cost of effluent discharge and treatment services. These are commonly used by local authorities for the collection and treatment of solid waste and sewage water. In many cases such charges are flat-rate and therefore fail to act as an economic incentive to pollute less.

3. Product charges are applied to the prices of products which create pollution either as they are manufactured, consumed or disposed of: for example, lubricants, sulphur in fuels, fertiliser, mercury and cadmium batteries, non-returnable containers, pesticides. Product charges are intended to modify the relative prices of the products and/or to finance collection and treatment systems, such as deposit-refund systems.

4. Administrative charges are chiefly aimed at funding systems of licensing and licence monitoring. Many countries apply them: for example, a charge on registering new chemical products (Norway), or for the cost of studying and authorising activity which will cause pollution (Sweden) or for inspection of motor vehicles (United States).

5. Tax differentiation, a practice similar to product charges, modifies the relative prices of products by penalising those harmful to the environment. In several countries (Finland, Germany, Netherlands, Norway, Sweden, Switzerland, United Kingdom), tax differentiation on petrol is aimed at encouraging the use of lead-free petrol.

aim of emissions trading is twofold: first, to minimise the cost of pollution abatement by reducing emissions where marginal abatement costs are the lowest and second, to reconcile economic development with environmental protection by allowing new firms to set up activity in a given area without increasing the total amount of polluting emissions within it. In the face of the seemingly superior efficiency of tradeable emission allowances, one may ask why this system is not more widespread. One reason may be that a change from a regulatory to an incentive-based system redistributes wealth. In particular, such schemes would generally be unfavourable to firms that currently hold existing free-of-charge emission permits.

Economic instruments have several appealing properties, if properly designed. They can:

-- promote economic efficiency by allowing market agents themselves to decide upon the best way to reduce pollution; if the problem is to ensure proper pricing, economic instruments are intuitively appealing because they aim to treat market failures by adjusting prices for external effects;

-- provide permanent incentives for technological improvements: for instance, redefining property rights (e.g. emission trading) is attractive because their purpose is to correct the essence of market failures by assigning property rights or resource endowments to market agents;

-- reduce the size of the bureaucracy involved with regulatory approaches and minimise compliance costs; such approaches do not do away with all overhead costs, however, since, at a minimum, compliance must be monitored and enforced.

Regulations may take the form of emission licences that in some cases are coupled with or replaced by standards that polluters are obliged to meet (OECD, 1987). For example, technical standards or ambient quality standards are commonly used throughout the OECD countries for water quality and certain air pollutants. Chart G illustrates the tightening of standards for car emissions for three air pollutants.

In some cases, there are arguments for preferring regulation to economic instruments (5). These arguments, which are elaborated below, include:

-- substantial transaction costs of implementing certain economic instruments which may be lower under regulation, depending on the case;

-- the greater certainty of the effects of regulation on environmental quality may be more acceptable to legislators and/or electorates, although some economic instruments may be able to deliver the same certainty;

-- economic instruments may have politically unattractive effects on income distribution that are to some extent avoided, or at least masked, under direct regulation.

The enforcement of environmental policies will tend to generate transaction costs that may significantly influence policy efficiency (Coase, 1960). For instance, the efficiency of different policies depends heavily on the geographical diffusion of pollutants, with both damage costs and abatement costs of local pollution varying with geographical characteristics. When a small number of polluters is involved, such as with a single factory, this would tend to favour direct regulation. On the other hand, local regulations involve screening and compliance costs that could be reduced by using economic instruments, even though the latter may also involve monitoring and enforcement costs (6). New information technologies may reduce these costs substantially.

The argument that regulation minimises uncertainty for both polluters and governments has some intuitive appeal. It may in some cases be an advantage for polluters. However, the authorities still have to choose between either price corrections or volume corrections. If one wishes to minimise the uncertainty of reaching a specific volume goal, such as a "ceiling" on emissions, it would seem that this might equally be achieved by assigning property rights (emission trading) instead of by direct regulation. Furthermore, uncertainty paired with information imperfections and differences in transaction costs between interest groups may lead to elements of adverse effects on pollution under a regulatory regime.

In some cases, regulatory policies might be perceived as "fairer", and hence be politically more viable. On the other hand, the main reason for this preference is perhaps not that regulation is fairer in terms of income distribution, but rather that it is a more effective way of hiding the real costs of pollution control and who bears them.

No single instrument can be said in general to be superior to others with respect to environmental policies. Nor have any large surveys been conducted which can show the economy-wide potential for increasing economic efficiency by using more market-oriented instruments. Rather, the particular properties of each issue need to be studied in detail before policy recommendations can be made. Nevertheless, current regulatory regimes seem to suffer from complexities and distortions that potentially involve serious efficiency losses. Under a regulatory regime, market agents normally retain an economic incentive to pollute, due to the relatively inflexible nature of most regulations. Where economic instruments have replaced regulation, substantial savings have been achieved, as with tradeable emission rights for air pollutants in the United States. The costs of distorted incentives are of special concern in the context of long-run effects on technological development and economic growth. In the area of global pollution, the relative advantages of economic instruments would seem to be greater than in the case of many traditional pollution issues, since the cost of pollution does not depend on the location of the source.

III. ECONOMIC GROWTH AND THE ENVIRONMENT

A. Economy-wide aspects of environmental issues

Once the scale of either environmental damage or environmental abatement costs reaches sufficient proportions, the direction and magnitude of economy-wide effects become an important issue.

While monetary evaluation techniques of environmental damage have improved considerably, few aggregate damage estimates are available. Where there are estimates, as for Germany and the Netherlands in the mid-1980s, they vary by large amounts owing to different approaches (Table 6). The Dutch estimate shows damage of 1/2 to 1 per cent of GDP, while the German number is roughly 6 per cent of GDP. Both studies take pollution effects such as health, material, agricultural and ground water damage into account. The higher estimates in the case of Germany are largely due to allowing also for disamenity effects of air pollution and for the effect of noise on property values. While such aggregate estimates are, at best, "ball-park" numbers, they show that measured aggregate damage is a significant cost to the economy. No aggregate estimates over time are available for any country. Anecdotal evidence suggests that environmental pressures may have increased in some respects, but may have diminished in others such as with large reductions of traditional air and water pollutants.

Aggregate spending on abatement is also a significant fraction of GDP. Aggregate abatement expenditure by the public and business sectors is roughly 1 to 2 per cent of GDP for most countries (Table 7). For household expenditure, the statistics are sparser and more uncertain: in 1986, household spending on pollution abatement was estimated at 0.2 per cent of GDP in France and 0.4 per cent in the United States. Changes in expenditure as a per cent of GDP between 1978 and 1985 were small. Measured as investment shares for specific sectors, however, the picture is somewhat different. Environmental protection investment in energy-intensive industries was in some countries well above 10 per cent of total investment in certain sectors, notably for energy production in Germany (19 per cent), for the refining industry in the Netherlands (22 per cent) and for the steel and metals industry in the United States (11 per cent) (DRI, 1989).

The effects of abatement spending on economic growth have been evaluated using macroeconomic models (OECD, 1985a), a growth-accounting framework (Denison, 1985) and applied general equilibrium models (Jorgenson and Wilcoxen, 1989). Negative effects on growth range from being negligible to a moderate 0.2 per cent per annum in the case of the United States over the period 1973-82 (Jorgenson and Wilcoxen, 1989). The results reported by Jorgenson and Wilcoxen indicate that crowding-out effects of environmental control policies may have been under-estimated in previous studies (7). It is quite likely that low-cost measures have been taken to date, and that further abatement could involve higher costs. There is certainly concern that both damages and abatement costs may increase significantly, in particular with regard to some global issues such as climate change. Hence, an important issue is whether or not the current economic expansion path is sustainable in the long run.

B. Sustainable growth: concept and interpretation

The concept of sustainable economic growth is certainly not new. It was raised by Malthus and Ricardo, who speculated on the "natural" limits to growth, the former focusing on rapid population growth, the latter on the limitation of land resources. Recently, the Brundtland Report (WCED, 1987) focused on the concept of sustainable development, which was interpreted as achieving a range of global goals encompassing sustained economic growth, the elimination of poverty and deprivation, conservation of the environment and enhancement of the resource base. Researchers have tried to flesh out different definitions of sustainable development, with Pearce et al. (1989) citing 30 examples. To limit the scope of analysis, the paper focuses on the interaction between environmental developments and growth as conventionally defined.

If current economic growth leads to a decline in future welfare, measured as the per capita consumption potential of both marketable and environmental goods, the growth path would not be considered sustainable (Haveman, 1989). Hence, in per capita terms, sustainable growth can be defined as non-declining consumption potential -- or wealth, broadly defined. Consumption potential is in turn linked to future production potential and hence to capital stocks, measured in efficiency terms so as to include the effects of technological progress. If environmental resources are considered as part of the capital stock, then the total of man-made and environmental capital cannot decline if total consumption of marketed and environmental goods is to be sustained. Thus, in per capita terms, sustainable growth requires either non-declining stocks of both kinds of capital or sufficient substitution of productive capital for environmental capital to keep total capital stocks intact (8).

This raises the issue of the relationship between this "sustainability constraint" and the optimum principles discussed in Section II. The consumption -- or welfare -- potential will in each time period be an increasing function of the amounts of the two types of capital:

$$[1] \quad W = W(K,E)$$

where in each period in time and in per capita terms
W = consumption potential (welfare)
K = stock of man-made capital
E = stock of environmental capital

This equation may also be derived from the underlying welfare and production functions. Introducing the "sustainability constraint" -- that W is not allowed to decline in any period -- yields as a necessary and sufficient condition for sustainable development:

$$[2] \quad -q\dot{E} \leq \dot{K} \qquad \text{for } \dot{W} \geq 0$$

where $\dot{K}$, $\dot{W}$ and $\dot{E}$ are the changes in K, W and E over time and q is the real shadow price of environmental capital measured in terms of man-made capital, i.e.: $q = (W'_E)/(W'_K)$. Hence, q is the shadow price (or cost) attached to an incremental change in environmental capital, measured in terms of man-made capital. According to [2], sustainability requires that the real value of environmental depletion must not exceed the real value of net investment in man-made capital.

As discussed in Section II, the market cost of pollution (i.e. the price paid in the market for the use of environmental resources) will fall short of the real shadow cost as expressed by q -- the difference being the external costs imposed by polluters. The presence of external costs, which implies over-use of environmental resources, poses the inherent risk that the economy could follow an unsustainable path. Nevertheless, declines in the stock of environmental capital (E) still permit sustainable development as long as it is replaced by sufficient man-made capital; i.e. at the rate given in [2]. However, two factors militate against this outcome. First, as E falls, the marginal shadow price (q) of the remaining stock will rise and, hence, given unchanged market costs of pollution, so will the external costs. Second, even if the stock of environmental capital is stabilised, its shadow price will rise with welfare (i.e. with output) so long as the environment is not an inferior good.

Hence, for constant market costs of pollution, the total value of environmental degradation ($-q\dot{E}$) will keep rising with growth in output and man-made capital stocks. In order to prevent this loss of welfare, the market costs of pollution may eventually have to increase. To ensure sustainability, as well as to improve overall resource efficiency, the value of both types of capital should thus reflect their relative scarcity in the long run -- as expressed by shadow prices.

Some argue that substitution in the production process between the two types of capital will be high in the future, so that the accumulation of man-made capital and associated efficiency increases due to technological progress will offset environmental degradation sufficiently to keep the economy on a sustainable growth path. If this is the case, there should be little reason for concern about sustainability, as future generations will benefit from new opportunities.

Nevertheless, the known possibilities for substitution are limited and their expansion is far from clear. Population growth is likely to put further pressure on the environment. If the scope for substitution is limited, the market costs of environmental capital should increase rapidly as environmental resources degrade. Basically, the presence of externalities would then probably be unsustainable. In addition, the development and adaptation of technologies to induce sustainable growth may be largely determined by the correct pricing of environmental resources.

Thus, there is strong reason to believe that unless real market costs of pollution are rising towards the real shadow cost of environmental degradation, sustainable growth, as defined above, cannot be achieved in the long run. Moreover, as the environment is probably not an inferior good, the real shadow price of environmental services will continue to rise over time with economic growth and hence the market cost of pollution should increase accordingly -- as also follows from the discussion in Section II.

Given the significance of the costs of pollution and the shadow price of environmental capital, it would seem appropriate to use cost-benefit analysis to establish estimates for environmental damages and abatement costs. The United States, for instance, made all major regulations subject to a compulsory cost-benefit analysis in 1981 and similar techniques are also used in most other Member countries, though on a more irregular basis. The value of attempting environmentally-relevant cost-benefit estimates has been summarised by Schulz and Schulz (1989) as helping:

a) to make the real dimension of environmental pollution clearer;

b) to make the environmental debate more objective;

c) to direct scarce financial resources to those areas of the environment where they are most urgently needed;

d) to make polluters aware of the costs arising from their actions; and

e) to further develop statistical measures of welfare.

Two limitations of the cost-benefit approach can be identified on the benefit side. First, measurement of the concrete benefits (in terms of damage avoided) is inherently uncertain, although benefit studies can throw some light on the extent of environmental damage. Calculating monetary values for damages due to degradation of air quality, for instance, involves estimates of damages to property values, agricultural crop losses, health and so on, long into the future (OECD, 1989c; Pearce et al., 1989; Miltz, 1988; Freeman, 1985). Second, the general problem of putting a value on a public good arises in assessing the benefits from damage avoided. Willingness to pay for environmental quality, and thus the preferred trade-off between environmental and other goods, depends upon the preferences of the general public, as does the question of how to weigh the preferences of current and future generations. In practice, these preferences can only be made explicit through the political process.

Assessment of benefits can nevertheless make these processes more informed. Methods for calculating benefits, or damage avoided in the future, are summarised in OECD (1989c). Pearce et al. (1989) gives estimates of several "shadow" resource prices based on willingness-to-pay surveys and hedonic price estimates for the United Kingdom.

Analysis on the cost of abatement side, where greater precision may be possible, seems to have a more central role in informing political debate. Sound decisions can only be made knowing what the cost of abatement will be in terms of foregone consumption of other goods. This cost is a measure of the trade-offs associated with different degrees of environmental protection and needs to be presented as clearly and objectively as possible.

Several national studies have evaluated likely future emissions and concentration levels and policy options for reducing discharges to certain target levels. The Dutch National Environmental Policy Plan (NEPP, 1989) is the most comprehensive to date. It provides target values for emission, waste and noise reductions to the year 2010 (Table 8) and estimates of the costs and macroeconomic effects of different policy options. Several policy options are considered: a considerable further tightening of emission control legislation, intensification of energy conservation regulation, increases in levies and charges on pollutants and the stepping up of public sector investment. For the scenario with the most stringent targets, annual expenditure on environmental protection would double to 4 per cent of GDP by 2010 and GDP would be 4.2 per cent below baseline by the year 2010 (Table 9).

Similar studies have been carried out in Norway. In the SIMEN study (Bye et al., 1989), a policy analysis is carried out for stabilising CO_2 and decreasing SO_2 and NOx emissions substantially. In the base scenario -- involving no further policy measures -- emissions are projected to increase substantially by the year 2000. Scenarios with tighter regulations and higher pollution taxes suggest that the target of stabilising CO_2 emissions could be reached only by a substantial tax increase on fossil fuels, giving an increase in the real price of about 75 per cent. Such a tax increase induces a change in the fuel mix (towards natural gas and hydro power) and gains in energy efficiency. It would have to be complemented by additional regulatory measures to reach the targets for SO_2 and NOx. GDP would be 1 to 2 per cent below baseline by the year 2000, but sectoral output consequences would be much larger for some industries. In the "tax scenario", aggregate effects are mitigated by reductions in other market distortions. The net revenue increase due to fuel taxes, amounting to approximately 2 per cent of GDP, is used to cut direct taxes on labour and capital. Another study (Glomsrød et al., 1990) that investigates the effects of stabilising CO_2 emissions from 2000 onwards, gives similar findings. The relative price of fossil fuels would increase sharply and the average annual growth rate would be reduced by 1/4 percentage point compared to the baseline scenario.

C. Implications for policy, measurement and indicators

Public choices with respect to environmental protection can be framed in two ways -- in terms of physical standards (for emissions or ambient quality) or in terms of abatement cost objectives. Setting volume standards without adequate information about costs is insufficient and may lead to inefficient outcomes, as the error on costs would be open-ended. Deciding on a certain level of abatement costs, and reducing all emissions where abatement costs are smaller than this target level, would bring efficiency considerations more to the fore. This approach fits with implementing policy by means of economic instruments, but it would focus on costs rather than volumes, and leave the error margins largely on the volume side.

Framing choices in terms of abatement costs would have two advantages. First, it would make the implications of the decisions being contemplated more transparent. Second, in the presence of large uncertainties, it would avoid the risk that objectives would be set at too ambitious levels, given the costs of meeting the targets or the benefits to be realised. Too ambitious quantity targets could discredit the policy, and jeopardise the achievement of alternative goals that might have proved more sound.

Whether policy is implemented on the basis of cost or volume targets is probably less important than reducing uncertainty by highlighting the trade-offs between doing nothing, a little or a lot in terms of abatement. Thus, in either case, the choice between appropriate sets of objectives should be conditioned by available information on the costs and benefits of achieving these objectives.

The implementation of appropriate environmental policy instruments was discussed in general in Section II. In addition to the use of such instruments, policy choices on environmental protection may have implications for the efficiency of other sectors which impinge upon environmental issues, such as agriculture, transport and energy (9). Pressures on soil and water resources, for instance, are being made worse by existing agricultural policies in most countries which encourage intensive farming. Agricultural subsidy schemes are often such that trying to control the environmental damage, rather than correcting the inefficiency in agriculture, is either futile or extremely costly.

Moreover, the interactions between various policies and concerns over the efficiency of environmental policy brings up the issue of environmental tax reform. If charges on pollution were to increase, aggregate effects could be mitigated by lowering taxes on other inputs, such as labour and capital. This would be in accordance with general principles for efficient taxation: namely that taxes should first be levied on activities causing negative externalities.

Indicators of the discrepancy between actual developments and targets are required in order to monitor success or failure in meeting environmental objectives and hence to adjust policy as necessary. These indicators need to cover measures of emissions (or ambient quality), as well as measures of actual abatement costs. Developing indicators that link economic and environmental developments should enhance the integration of environmental and sectoral policies.

The System of National Accounts (SNA) records market transactions and gives imputations of some non-market transactions. Market-priced reductions in output due to environmental degradation are recorded as well as spending on abatement, waste disposal, environmental charges, etc. In connection with fairly disaggregated input-output tables the SNA may give a more accurate picture of monetary flows associated with environmental policies than survey-based results (Schäfer and Stahmer, 1989). Apart from the identification of these expenditures it is often argued that spending for defensive purposes, now included in final demand categories, should be reclassified to be intermediate inputs, thereby subtracting them from GDP. Alternatively, to develop a better measure of welfare, it has been proposed to deduct pollution costs directly from GDP numbers, reflecting for example the disamenity cost of breathing polluted air. However, such imputations imply a normative judgement of environmental quality, whereas the current GDP measure is aimed at monitoring factual market activity rather than general welfare levels. The treatment of environmental spending and degradation will probably not be changed in any fundamental way during the forthcoming revisions to the SNA (Blades, 1989) (10).

Nevertheless, knowledge of environmental policy objectives makes it possible to calculate the cost of the measures needed to achieve such objectives, and hence to construct a "green" GDP. Uno (1988) and Uno and Shishido (1988), for example, estimate that the cost of moving to more stringent environmental standards in Japan would have reduced the level of GDP by about 4 per cent of GDP in 1960. With the actual tightening of standards, these costs had fallen to about 2 per cent of GDP by 1985. The introduction of a similar approach is contemplated in the Netherlands (Hueting, 1989).

An alternative broad aggregate indicator that has been suggested is the estimation of service flows from total environmental capital. Given that opportunity costs can be calculated by using targeted abatement costs, these prices can be connected to information on actual pollution or resource stocks in physical units. Hence, available information on the state of the environment may be translated into measures of flows of environmental services and estimates of damage caused by degradation of environmental resources. The use of extended (satellite) accounts is a comprehensive approach which links physical stocks of resources (material and environmental) to national balance sheets and resource use to (national) flow accounts. Such physical accounts -- which have been established in France and Norway -- would seem useful tools for including environmental assets in calculations of wealth (Pearce et al., 1989; Repetto and Pezzey, 1990). However, there are still many practical difficulties regarding both the actual measurement of physical stocks and their conversion into monetary values (11).

IV. CURRENT POLICY ISSUES AND THE INTERNATIONAL DIMENSION

A. Transborder air pollution

In current debates, global and regional air pollution issues have emerged as a particular problem, largely due to the complications involved in setting up credible environmental policies across borders, but also because of the potential for high damages. Air pollution is a residual of production stemming from the use of polluting inputs such as fossil fuels and industrial chemicals (Chart H). In particular, fossil fuel combustion contributes between 50 and 90 per cent of global emissions of major air pollutants such as SO_2, NOx, CO_2 and particulates (Table 10). Emissions of major air pollutants are thus related to overall energy intensity, as shown in Chart F, although emissions vary according to the composition of fuels used and the use of end-of-pipe rinsing technologies. Countries with relatively high energy prices tend to exhibit low per capita levels of energy intensity and vice versa (Chart I).

The relationship between fuel use and pollution varies across different pollutants as does the possibility of "end-of-pipe" abatement technology. Such technology can restrain emissions of most pollutants but not all. Where "end-of-pipe" abatement technologies exist, such as catalytic converters for NOx and sulphur "scrubbers" for SO_2, there is no complete complementarity between fuel use and pollution. In this case, direct emission charges would be preferable, if emissions can be monitored relatively easily. However, emission charges are in many cases impractical to implement due to the high associated monitoring costs (for example, actual emissions by cars). Instead, governments have therefore often used technology standards or other forms of regulation to reduce air pollution (12) (cf. the discussion in Section II).

Perfect complementarity does exist, however, between the use of a given fossil fuel and CO_2 emissions, as no rinsing technology is currently available for CO_2. Increases in opportunity costs for pollution could thus involve a similar increase in the shadow price of fossil fuels in order to achieve sustainable growth. Furthermore, as long as pollution stocks -- and hence, marginal pollution damage -- increase, sustainability requires a continued rise in pollution-related input shadow prices. To reduce CO_2 emissions, therefore, raising the price of primary and easily defined fossil fuel inputs according to their carbon content, for instance by putting a "carbon tax" on fossil fuels, might be more cost efficient than regulation or direct charges on emissions.

The effect of such a tax increase would depend primarily on long-run price elasticities and substitution possibilities for primary energy sources. Second, if saving is responsive to the rate of return, future capital accumulation -- and hence growth -- will be lower. Finally, the overall effects on output may crucially depend on the redistribution of the increased tax revenues. If policies are made fiscally neutral so that increases in fuel taxes are linked with reductions in other taxes, the overall costs may be minimised at a relatively low level. A cut in taxes on labour or capital, for instance, will reduce existing distortions and is likely to increase aggregate supply. The terms of trade could be improved substantially for energy importers in the short and medium term, depending on price responses from the supply side of the energy markets (Borges and Goulder, 1984).

One would expect the price elasticities of demand for a particular fuel to be very high over a time period long enough to allow replacement of business and fuel-handling equipment, with the elasticity for the aggregate of all fossil fuels much lower because of more limited substitution possibilities (13). Estimates of own-price elasticities tend not to be comforting, in this respect, however. Even taking a more optimistic view of inter-fuel substitution possibilities, one does not arrive at a markedly more favourable scenario because at present non-fossil fuel energy sources are limited on the supply side (as with hydroelectric power) or raise other environmental concerns (as with nuclear fission). In the end, the extent to which high fossil fuel prices might induce energy conservation and the development of clean energy substitutes (e.g. solar energy) may depend largely on the effect of these prices on technological innovation. On the other hand, if alternative technology -- or so-called "back-stop" technology -- turns out to be relatively cheap in the long run, substitution may be greatly enhanced. True, long-run price elasticities could thus be greater than estimated, as the effect of relative price changes builds up gradually. Substantial emission reductions might also be achieved by switching from "dirty" to "clean" fossil fuels, e.g. from coal to natural gas.

The sharp increase in oil and gas prices in the mid-1970s lead to a large change in the fuel mix which closely shadowed changes in relative prices (Table 11). Fossil fuel prices also differ considerably across countries, mainly reflecting differences in taxation. Gasoline prices, for instance, were four times higher in Italy than they were in the United States in 1988, nearly all the difference being due to taxation. In general, taxation of gasoline is lightest in the United States and Canada, where the tax component is about a third of the end-user price (Chart J).

There is great uncertainty about the benefits of CO_2 emission reductions, in other words about the scale and consequences of future global warming (see the box overleaf). A survey of various scenarios for future CO_2 emissions and other trace gases shows that global emissions of CO_2 85 years from now might be anything between 15 times higher or slightly lower than today (Chart K) (Environmental Resources Limited, 1988). The large differences in

THE GREENHOUSE EFFECT

1. Perhaps the most complex global environmental issue now under discussion is the so-called greenhouse effect. The expression reflects the fact that certain gases in the atmosphere act as a jacket that keeps warmth (infra-red rays) from escaping from the atmosphere, much in the same way as glass traps heat in a greenhouse. These greenhouse gases (principally carbon dioxide, but also CFCs, methane (CH_4) and nitrous oxide (N_2O) -- see Chart L) could cause the average global surface temperature to rise, resulting in a range of counterbalancing regional climatic changes. The Earth's atmospheric systems are, however, not understood sufficiently well to trace the effects of increased greenhouse gas concentration accurately. Estimates are that average global temperatures could rise by as much as 5°C by the middle of the next century, depending on the amount of increase in greenhouse gas concentrations and second-order reactions in ecosystems. To put this in perspective, average global temperatures have fluctuated by as much as 10°C over the last 160 000 years (Houghton & Woodwell, 1989). According to most climatic research results, global temperatures have increased by 0.3 to 0.7°C over the last century. While this increase cannot be definitively attributed to the greenhouse effect, it is consistent with model simulations of climate changes caused by greenhouse gases, given the uncertain delay caused by ocean heat intake (Houghton & Woodwell, 1989 and EPA, 1989).

2. The concentration of most greenhouse gases is dependent not only on cumulative emissions, but also on the amount of natural absorption of these gases. This is particularly the case for Earth's carbon balance, as most carbon on earth is stocked in natural carbon sinks, and not in the atmosphere. These sinks consist mainly of carbon stocked in plants on land (such as forests), in unused fossil fuels (mainly coal) and in the oceans, which are the largest carbon sink.

3. The overwhelming source of man-made emissions of greenhouse gases is use of fossil fuels like coal, oil and natural gas. In 1987, 45 per cent of global CO_2 emissions originated in OECD countries, which is less than their GNP share, but substantially higher than their share of world population (Table 12). The contribution from currently less developed countries could become larger if they developed along the lines of OECD economies, but the pollution from Eastern European countries, which currently contribute a disproportionately large share of CO_2 emissions, could decline.

4. The greenhouse effect -- if it occurs -- would probably cause other climatic changes and an associated rise in the sea level. Some climate models indicate a transfer of rain patterns to temperate zones from the sub-tropical and Mediterranean zones. If so, this may imply large adjustment costs as today's major areas for cereal production would be affected. At predicted warming rates, increased mortality of trees and other plants is a likely outcome. It is likewise possible that temperature changes might result in more rapid developments, both in the form of flooding and sudden changes in weather patterns. However, the long-run climate effects of global warming are uncertain. Also, local factors are likely to have a major effect on the outcome for any particular geographic location (see Houghton & Woodwell (1989) for a comprehensive overview of the issue).

the various projections highlight the uncertainty surrounding long-term predictions:

a) Projections of future population growth and overall technical progress are the most important ingredients for estimating future output growth: if global growth over the next 85 years were 2 per cent, output would increase about five times, if it were 3 per cent, it would go up twelve times;

b) The rate of energy efficiency improvement, which critically depends on relative price developments, mitigates the detrimental effects of fast overall growth;

c) Again depending on relative price developments, alternative energy sources might become economically viable or be searched for more intensively;

d) Investment in regenerative capability (e.g. reforestation) would increase the net intake of carbon in ecosystems.

The IEA has recently produced various policy scenarios for reducing CO_2 emissions (IEA, 1990). In a base case, CO_2 emissions increase globally by about 50 per cent from 1987 to 2005, with emissions from OECD countries rising by roughly 25 per cent. The much faster increase of emissions by non-OECD countries results from the combination of high population growth and continued energy deepening as the economies of the LDCs and NIEs develop. In the study, two policy scenarios are investigated: the effect of substitution towards nuclear energy and the effect of a carbon tax in the OECD countries, which leads to a rise in crude oil prices of almost 50 per cent. The carbon tax is applied in the OECD countries only. In both cases, the projected effects on CO_2 emissions and concentration levels are fairly modest (Table 13). The carbon tax is estimated to reduce CO_2 emissions from OECD countries by a little over 10 per cent, compared with the base case. In other words, the projections suggest that CO_2 emissions will continue to rise even with a carbon tax of this magnitude. The effect on CO_2 concentration levels are even smaller, due to the relatively small share of annual emissions in total CO_2 concentration.

Various other model simulations also indicate the crucial importance of the assumptions made about production technologies and price elasticities. A survey of energy model simulations by Nordhaus (1990a) nevertheless confirms a conclusion that would hold qualitatively over the range of most estimates of elasticities: a carbon tax would need to be large, increasing over time and in the long run encompass more than the OECD countries to stabilise emissions at current levels. Alternative regulatory approaches would have economic implications that were at least as large.

Uncertainty about the damage from a given level of emissions is still much greater than that concerning what emissions will be. As noted earlier, there is considerable debate in the scientific community about the implications for climate. Nordhaus (1990) is one of the first to investigate the <u>costs and benefits of alternative policy approaches</u> to the greenhouse effect.

Using a simplified growth-accounting framework, Nordhaus gives rudimentary estimates of the damages from a doubling of trace gas concentrations in 2050 of from 1/4 to 2 per cent of gross output, the "middle-damage" case being estimated at roughly 1 per cent of world GDP. Efficient policy should aim at equating this shadow damage of greenhouse warming to the cost of abatement. The derived optimal strategy in the "middle-damage" case calls for a reduction of greenhouse gas emissions by 17 per cent compared with annual emissions in the baseline scenario, including a large reduction of the use of CFCs and some reduction of CO_2 emissions. It is relatively cheap to substitute for CFCs, the most "efficient" greenhouse gas, it is more expensive to reduce CO_2 emissions through a carbon tax, while reforestation costs may become prohibitive as forests compete with other land uses. Using the low-damage estimate, the optimal reduction of greenhouse gas emissions is still substantial at 10 per cent of emissions. In the high-damage event, the rate of reduction rises to 47 per cent of total greenhouse gas emissions, as compared to baseline (all figures are in CO_2-equivalent units).

On the basis of what is known about costs and benefits, and about substitution possibilities between energy sources, it would seem that CO_2 emissions could be reduced significantly over the longer term. Given complementarity between fossil fuel use and other air pollutants, such as NOx and SO_2, a rise in fuel prices would then also contribute to a reduction in the emissions of these pollutants. Substantial reductions in emissions would be needed, however, to stabilise CO_2 concentration levels. Given the likely continued increase in energy demand, one might expect the implied shadow cost -- the equivalent "carbon tax" on fuels -- to be substantial.

The dimensions of the climate change issue are large -- both in terms of potential, although as yet uncertain, damage costs and in terms of the adjustment needed to stabilise greenhouse gas concentrations. Hence, if policy is aimed at limiting greenhouse gas emissions, a sequential approach, by which low-cost measures would be phased in before measures with higher costs, could be desirable to reduce disruption and to allow time for adaptation. There might be scope for considerable overall improvements of efficiency that could at the same time increase future options and flexibility. This approach would seem likely to be particularly fruitful with regard to activities and market conditions closely tied to potential environmental degradation, such as:

-- Increased taxation of the perceived external costs of air pollution and -- if tax revenues were to remain constant -- a consequent decrease in other tax rates. If applied gradually and on a general basis, a shift in taxation towards charges on externalities ("Pigovian" taxes) could result in overall efficiency gains and increase the potential for and profitability of innovations in "clean" technologies;

-- A standardisation of tax rates across fuels to better reflect their environmental impact, so as to minimise distortions in consumption patterns due to existing tax differentials, for instance between close substitutes such as gasoline and diesel or coal and gas;

-- Policies in the field of urban congestion and related transport policy incentives that, if applied consistently, could provide overall efficiency gains and at the same time reduce emissions of air pollutants -- including emissions of CO_2 (14). Even when excluding environmental damages, the social costs of urban traffic congestion and motorised goods transport are often much higher than the private costs, and also higher than those of near substitutes such as public transport and railways (ECMT, 1989).

B. Uncertainty, environmental risks and main policy options

Substantial work has already been done in estimating the effects of various economic developments on environmental variables (see Section III). The scientific community has also started to disentangle some of the main inter-relationships and cycles within and between ecosystems, such as the carbon cycle and the effects of CFCs on the ozone layer. However, major uncertainties persist as regards our understanding of these systems -- the accumulation, the interaction and the geographical diffusion of pollutants -- and their long-term effects on the economy, as illustrated in Chart M (15). Damage, in both physical and economic terms, is particularly uncertain. The physical and chemical processes at work could induce unstable dynamic processes. Long lags and natural threshold effects further raise the possibility that very large and perhaps irreversible damage could become unavoidable by the time there was conclusive direct evidence of damage. Costs of abatement are also uncertain, but, as noted earlier, they would be likely to be high if the objective was to prevent climate change. While recent research and policy experience have provided valuable knowledge, abatement costs often depend on unknown or hardly predictable technological developments that make the effects of control policies equally difficult to predict.

Two alternative response strategies can be distinguished: reaction and pre-emption. Reaction means taking action only as damage becomes manifest. It could also involve adaptive measures such as construction of dikes and dams to minimise the costs of a sea level rise. A pre-emptive policy would involve action to avoid the damage occurring in the first place (16), such as efforts to reduce greenhouse gas emissions or invest in an increase in carbon sinks through reforestation. While a purely reactive strategy might well turn out to be the least disruptive, it could also be the high-risk strategy, since it might induce action too late and fail to prevent some very costly outcomes. As a practical matter, the issue is where on the spectrum between purely reactive and fully pre-emptive action policies ought to be set.

The attitude towards environmental risks may depend on the risk aversion of society as a whole, society's time horizon and discount rate, the magnitude of risks involved and the expected possibilities for substitution or technological improvements. Basically, these large-scale and long-term environmental issues pose a policy problem involving the social discounting of low-probability but high-damage events. One might think of these events as occurring in a large lottery with mostly tolerable outcomes -- except for a few disastrous ones. The issue is what, if anything, governments could do to reduce the probability of such outcomes even further, and whether it would be worth it. In particular, the question arises as to whether policies should be instigated to deal with improbable but potentially calamitous events.

The risk of committing society to substantial future damage costs is closely connected to the potential for irreversible resource depletion, such as might be the case for CFC emissions -- chlor-molecules can reduce ozone molecules as late as 70 years after the emissions themselves -- or for hazardous wastes that accumulate over time without disintegrating. The possibility of irreversibility poses a particular risk problem, which may be stated as follows: Suppose that degradation of an environmental resource may lead to infinite recovery costs. The related expected damage costs may not be large enough in themselves to validate prevention of the resource being diminished. However, infinite recovery costs imply that the resource is irreversibly lost, and thus that there has been a narrowing down of alternative resource uses. This loss of alternatives may -- in an uncertain world -- have a value in itself, a so-called "option value", which in many cases may exceed the costs of preventing further depletion. Siebert (1987) describes an option value as "an insurance premium against the irreversible loss of an alternative" (17).

Pearce et al. (1989) stresses the way in which the interface between technological optimism and risks may influence policy (Chart N). He indicates that, although one may be optimistic as regards future technological possibilities, high risk aversion or the presence of potential irreversibilities might nevertheless justify an "insurance approach" -- but of course not regardless of its costs.

The risk problem that has to be considered thus concerns also the robustness of policy. Adopting an extreme strategy carries high risks with respect to the costs implied, be it risks of high environmental damage or over-investment in environmental safety. Whatever strategy is chosen, policy should be kept flexible so as to be able to take new information into account.

C. International co-operation on global and regional issues

Environmental agreements and conventions are covering a broadening field of policy areas, so that the cumulative effect on overall economic performance may become considerable. As the scope of environmental policy widens, it is increasingly important not to neglect the effects of control policies on overall investment and its allocation. Also, effects on the world economy and on international trade are likely to grow. Resort to trade restrictions on environmental grounds could pose a further threat to longer-term growth prospects.

A main conclusion of work by the OECD on transborder pollution, which dates back to the early 1970s, was that in order to ensure economic efficiency across country borders, it would be convenient to internalise both the costs of pollution and the costs of abatement. This led to the suggestion of the so-called "mutual compensation principle". The mutual compensation principle is a counterpart to the Polluter Pays Principle to deal with the efficient distribution of abatement and pollution costs between countries (18). The polluter should pay for the pollution damage, thus encouraging polluting countries to take account of the external costs of pollution, while the "victim" country should pay for abatement, giving it an incentive to absorb pollution as long as this is the cheapest solution. Otherwise, if polluting countries are not compensated for at least part of the abatement cost, they have very little incentive to agree on cleaning up polluting activities that induce damage in other countries.

Since the mutual compensation principle was suggested, it has not been applied directly to any significant pollution issue. Two important reasons seem to be:

-- The polluting country has no incentive to agree to mutual compensation as long as the "victim" will otherwise have to pay the damage costs. In other words, the polluting country would always be in the strongest position before and during negotiations;

-- Because of the uncertainties involved, the "victims" of pollution have usually not easily been able to prove that the pollution is really causing economic damage. In many cases, it is difficult to prove even the extent of environmental damage, let alone to identify the polluter (atmospheric pollution, for instance, usually originates in more than one country).

As a consequence, the international community has started to take concerted action through international agreements and conventions on general policy goals rather than working out detailed compensation systems. The United Nations is the main negotiating body. Most OECD countries participate in discussions and negotiations under the auspices of the U.N. Economic Commission for Europe (ECE), which includes North American, as well as European Members of OECD and, importantly, Eastern European countries. The auspices of the U.N. Environmental Programme (UNEP) and various regional agreements under the UNEP framework have also played an important role. Over the years, a substantial number of agreements and conventions have been signed by varying numbers of participating countries. Some of the more important agreements as regards international or global pollution are shown in Table 14.

The negotiation of international agreements is an ongoing and continuous process. Agreements or conventions that are likely or foreseeable in the near future include:

-- A protocol on volatile organic compounds (VOC) which might be included under the Convention on transborder air pollution;

-- Conventions on climate change and the emission of greenhouse gases arising from the work of the Intergovernmental Panel on Climate Change (IPCC), which was set up by UNEP and the World Meteorological Organisation. The process may result in a proposal to the U.N. Conference in 1992.

Since the agreements and conventions usually do not include specific recommendations as regards policy instruments, it is often difficult to judge their effectiveness. Moreover, most of the agreements involving specific and quantified goals for emission reductions have "deadlines" well into the 1990s and have thus not yet been put to the test. Nevertheless, for some substances, notably for sulphur oxide emissions, there has been considerable scope for reducing emissions using traditional abatement technologies and also considerable progress (see Section II).

One feature dominating the quantitative agreements to date is that they have involved equi-proportional reduction targets for signatories. Such proportionate reductions generally involve efficiency losses, since both abatement costs and the consequence of damages vary between countries. In general, a less costly solution would be to let emission reductions vary according to abatement costs. This might not be of great importance if abatement costs are very limited, if regulations would have been imposed anyway (as might have been the case for SOx) or if the substance in question in any case will be totally banned in the near future (as now looks possible for CFCs). However, if the degree of international co-operation on these issues increases, the need to improve economic efficiency will be more pronounced. For instance, a proportionate cut in CO_2 emissions would involve significant efficiency losses as fuel and energy efficiency vary enormously between countries.

To ensure transnational economic efficiency, further efforts will be needed to reduce differences in marginal abatement costs between countries (see for instance Whalley and Wigle, 1989). What this amounts to is an international agreement on cost objectives, rather than on equi-proportional quantity reductions. For instance, there would seem to be scope for substantial efficiency gains by allocating funds at the margin towards low-cost measures in Eastern Europe rather than high-cost measures in the OECD countries.

Monitoring the application of environmental policy instruments across several countries would, however, require substantial resources. Another and perhaps more appealing alternative, therefore, could be to agree quotas on emissions of polluting substances and then make these quotas tradeable between countries. Such quota trading would come close to the "mutual compensation principle" in that both abatement and damage costs would be internalised, at least at the country level, with the decision on whether to buy or sell quotas. The possibility of setting up a system of tradeable permits or quotas has been proposed in several connections, for instance to optimise the CFC phase-out process and to improve the efficiency of water management (OECD, 1989a). Similarly, introducing tradeable CO_2 quotas as an alternative to proportionate cuts in emissions across countries would be an obvious possibility. A serious obstacle to this approach, however, is the difficulties involved in negotiating the initial distribution of the property rights assigned. For instance, it is not clear whether the initial quota distribution should be based on current emissions, emissions per capita or per GDP unit, or any other feasible criterion. Substantial income transfers could be involved, particularly if quotas were fixed in per capita terms and later extended to LDCs.

While it is conceivable that some countries could agree on policies to counter global environmental problems, countries not party to the agreement might conduct policies which would significantly reduce the value of the agreement in the long run. One possible solution to this problem would be to provide at least some economic incentive for such countries that would be based on conditions similar to those faced by signatories to an agreement. For instance, transfers could be conditioned on the basis of the same CO_2 quotas as applied by a hypothetical quotas-trading agreement. A somewhat different concept that has been proposed in connection with CFCs, is to make "green" technology easily available through subsidies from a transfer fund. However, until counter-measures can be agreed upon by at least some key countries, the possibility of introducing transfer mechanisms to third parties remains highly hypothetical.

The appropriate response to global environmental problems will probably have to involve concerted international efforts, but setting up a credible global environmental policy is by no means a trivial task and one that will undoubtedly take time and patience. This underlines the need to proceed in steps, identifying and implementing the least cost and most clearly-agreed policies and moving to more ambitious proposals as evidence and international consensus become clearer.

NOTES

1. The emissions of chlorofluorocarbons (CFCs) and halons are believed to deplete stratospheric ozone through a chemical process as chlor-atoms are dissolved from the CFC molecules under the influence of solar radiation. Stratospheric ozone protects Earth's surface from a major part of the ultraviolet rays that would otherwise reach the lower atmosphere. It is widely thought that above some threshold level of CFC and halon concentrations, which has not been well defined, the ozone layer will be reduced. The data on reductions in the ozone layer in Table 2 lead many to argue that the "tolerance level" has already been reached. However, it remains controversial whether the observed reductions are caused by man-made emissions or by other factors such as long-term cycles in weather patterns (Singer, 1989).

2. See, for example, Baumol & Oates (1988); Herfindahl & Kneese (1974) and Howe (1979).

3. In a broad sense, the term "economic instrument" covers instruments involving a financial transfer between polluters and the community. Economic instruments operate as financial incentives to polluters, who then choose their levels of inputs and output accordingly. Broadly speaking, polluters may opt to pollute and pay for it or invest in pollution reductions.

4. See OECD (1989b).

5. See, for instance, Bohm & Russell (1985), Baumol and Oates (1988) and Coase (1960).

6. As regards spatial differentiation of economic instruments, Siebert (1989) points out that "... a heavily polluted area requires higher emission taxes (than other less polluted areas)... Assume, for instance, one were to raise emission taxes for SO_2 generally in Europe in order to reduce the level of pollutants ambient in the environment and thereby reduce the transborder (pollution) problem. Then, abatement clearly would not be cost minimising, and the costs of environmental quality would be too high. Definitely, such an approach would not even be second best." On the other hand, Baumol and Oates (1988) argue that the transaction cost example rests heavily on the number of economic agents involved. If there are many involved, properly designed economic instruments could still be more efficient.

7. According to Jorgenson and Wilcoxen, the effects of pollution control are significantly magnified by its impact on capital service prices, and thus repercussions through capital markets would seem to be a major explanation of the difference in results.

8. See, e.g. Pearce (1989) or Haveman (1989) for an elaboration.

9. The OECD has carried out case studies for several sectors. Sectoral studies completed so far relate to agriculture (OECD, 1989d), energy (IEA, 1989), transport (ECMT, 1989) and water resources (OECD, 1989e), but it does not seem appropriate to review policies in all these areas here. However, the issue of air pollution reductions in general, and climate change in particular, are used in Section IV to clarify issues.

10. Several attempts have been made to construct measures of welfare, which are more comprehensive than GDP estimates. Eisner (1988) surveys the U.S. literature on Extended Accounts. Such measures impute values for household work, leisure, etc. Concerning environmental disamenity, social costs of economic activity are subtracted, which are not internalised as private cost. In the accounts proposed by Nordhaus and Tobin, for example, disamenities of urban life include pollution, litter, congestion, noise, insecurity, buildings and advertisements offensive to taste, etc.

11. The literature on satellite accounts shows that there are several controversial issues, especially as regards the selection of discount, depreciation and depletion rates or the valuation of intangibles such as biological diversity. Nobody has yet suggested an adequate treatment of global problems that may result in uncertain damage far in the future.

12. It is estimated that for the United States 80 per cent of pollution abatement investment between 1973 and 1980 consisted of end-of-line treatment. For Denmark the proportion was 70 per cent between 1975 and 1980 (see IEA, 1989). IEA (1989) and IEA (1989a) give an extensive overview of technological developments concerning abatement technology and improved energy efficiency.

13. Mittelstädt (1983) reviews the literature on inter-fuel substitution elasticities as well as for elasticities for total energy input and other factors of production.

14. See OECD (1988).

15. For a categorisation of uncertainties, see for instance Siebert (1987).

16. See, for example, Pearce et al. (1989) for an elaboration.

17. See, for instance, Krutilla & Fisher (1975), Henry (1974) and Arrow and Fisher (1974) for an elaboration.

18. The so-called mutual compensation principle was suggested as follows; " ... the polluting country pays a 'pollution tax' related to the cost of damage estimated by the polluted country while the polluted country pays a 'treatment tax' related to the cost of pollution control as estimated by the polluting country. The purpose of the 'pollution tax' is to induce the polluting country to take suitable pollution control measures and the 'treatment tax' is intended to encourage the polluted country to accept the cost of residual damage... Like all economic instruments, it (the system) is based on the assumption that countries try to minimise the total costs due to pollution..." (OECD, 1976).

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Table 1

Categories and effects of air pollutants

Pollutant	Direct effects	Indirect effects
Traditional air pollutants		
Carbon monoxide (CO)	Interferes with absorption of oxygen that can cause adverse health effects on central nervous system, exacerbating heart diseases	
Nitrous oxides (NOx)	Effects on respiratory system (irritation, oedema and emphysema), in particular in combination with other atmospheric irritants	Forms nitric acid through chemical processes in the atmosphere and thereby a cause of acid rain and fog
	Detrimental effects on dyes, fabrics, rubber	
	Adverse effect on vegetation (more pronounced when occuring with high SOx concentration)	Together with hydro-carbon forms photochemical pronounced when occurring with high oxidants that have adverse effects on vegetation (living conditions, crop yields)
Sulphur oxides (SOx)	Adverse effects on respiratory system	Forms sulphuric acid when disolved in water, which affects both close vegetation and buildings as well as formation of acid rain
Hydro-carbons (HC)	Class of volatile organic-compounds (VOC), which is toxic to humans in high concentrations (aldehydes, benzene, organic acids)	Together with NOx, HC forms photo-chemical oxidants (ozone in the lower atmosphere) that have adverse effects on vegetation (living conditions, crop yields)
	Adverse effects on plants (ethene)	
Lead (Pb)	Damages various processes in body functions, such as kidney, liver, reproductive system, blood formation, basic celular processes and brain functions (at high concentration levels)	
Particulate matter (aerosols)	Toxic or carry toxic substances absorbed onto its surface	
	Reduces visibility ("smog")	
	Soiling of fabrics and buildings	
Other air pollutants		
Chlorofluoro-carbons (CFCs)		Class of chemical compounds that destroy ozone in the upper atmosphere when exosed for solar radiation. Also a greenhouse gas (see below)
Carbon dioxide (CO_2) Methane (CH_4)		"Greenhouse gases" that absorbs infra-red radiation and thus may increase the temperature in the lower atmosphere.

Source: OECD (1989), OECD (1988).

Table 2

Reductions in stratospheric ozone and cumulative release of CFCs to the atmosphere 1969-1986

	Average per cent reductions		
	Latitudes		
	30-39°N	40-52°N	53-64°N
Summer	1 3/4	2	1/4
Winter	2 1/4	4 1/2	6 1/4
Yearly average	2	3	2 1/4
	Cumulative release of CFC-11 and CFC-12 (1000 tonnes)		
	1969	1980	1986
CFC-11	1 260	4 380	6 130
CFC-12	2 380	6 690	9 500

Source: U.N. (1988), OECD (1989).

Table 3

Abatement expenditure by sector
(Per cent of total expenditure, 1985)

	United States	Germany (a)	France	United Kingdom	Netherlands
Water	50.5	52.2	52.2	37.6	45.6
Waste	23.2	20.7	33.6	33.9	26.2
Air	27.4	20.8	11.5	25.4	12.6
Other (b)	-1.1	6.3	2.7	3.1	15.6

a) 1984.

b) Other expenditure include items such as control of noise and radiation; in the case of the United States the negative sign reflects the fact that costs recovered due to resource recovery are deducted from the other expenditure.

Source: OECD (1990).

Table 4

Policy instruments for environmental policies

ECONOMIC INSTRUMENTS	
Redefining property rights	Tradeable emission permits; Liability insurance legislation.
Charge systems	Effluent charges, user charges, product charges and administrative charges. Product charges would be for instance charges on the content of pollutants in products or input factors, whereas effluent charges and user charges aim directly at charging the cost of resource use.
Subsidies	Financial aid in installing new technology; Subsidies to environmental R&D expenditure (often in conflict with PPP).
Deposit-refund systems	Combines charges and subsidies so as to provide incentives to return pollutants for recycling. Particularly relevant to waste management.
Enforcement incentives	Non-compliance fees, performance bonds. Although enforcement incentives can be regarded as a type of economic instruments, they are inseparable from regulatory measures.
REGULATION	
Standards	Effluent standards, ambient standards, technology standards. Setting requirements to be met usually by a limited number of market agents such as certain industries or individual companies.
Resource use quotas	Emission quotas, harvesting quotas (e.g. fisheries); By allowing quotas to be traded among market agents, the quota system would be transformed to a system of tradeable permits.
Negotiation	Negotiating rules to be set up for a particular industry or company. The distinction between this form and other types of regulation is that enforcement is often left to the industry itself (subject to the threat of further measures in the future).

Source: OECD (1989b).

Table 5

Application of different types of charges

	Type of charge							
	Effluent charges				User charges	Product charges	Administrative charges	Tax differentiation
	Air	Water	Waste	Noise				
Australia		x	x		x		x	
Belgium			x		x		x	
Canada					x			
Denmark					x	x	x	x
Finland					x	x	x	x
France	x	x		x	x	x		
Germany		x		x	x	x	x	
Italy		x			x	x		
Japan	x			x				
Netherlands		x	x	x	x	x	x	x
Norway					x	x	x	x
Sweden					x	x	x	x
Switzerland				x	x		x	
United Kingdom				x	x		x	x
United States			x	x	x		x	

Source: OECD, (1989b).

Table 6

Damage estimates for Germany and the Netherlands

	Germany	Netherlands (a)
	DM bil., 1983/85	Gld bil., 1985
Air pollution		
Health, crops, buildings, etc.	10.3	1.7-2.8
Disamenity	48.0	..
Water pollution	9.3	0.3-0.9
Noise	35.4	0.1
Total	103.0	2.1-3.8
% of GDP	6.0	0.5-0.9

a) Excludes disamenity effects.

Source: OECD (1989c).

Table 7

Abatement expenditure
(per cent of GDP)

		1978	1985
United States	Total	1.6	1.5
	Public	0.7	0.6
Japan	Public	1.5	1.2
Germany	Total	1.3	1.5
	Public	0.8	0.8
France	Total	..	0.9
	Public	..	0.6
United Kingdom	Total	1.7 (1977)	1.3
	Public	0.8 (1977)	0.6
Canada	Public	1.1	0.8
Austria	Total	1.1	..
	Public	0.8	..
Denmark	Public	0.9	0.8
Finland	Public	..	0.3
Greece	Public	0.3	..
Ireland	Public	1.0	..
Netherlands	Total	1.1 (1980)	1.3
	Public	0.9	1.0
Norway	Total	..	0.8
	Public	0.8	0.5
Sweden	Public	0.8	0.7 (1986)
Switzerland	Public	1.0	..

Note: Data cover operating expenses and investment expenditure by government and the goods producing business sector. In some cases outlays on charges and fees are also included. Coverage of data differs considerably between countries.

Source: OECD (1990).

Table 8

Dutch emission scenarios
(per cent changes)

	Results in 2010		
	Scenario I	Scenario II	Scenario III
CO_2	+35	+35	-20 to -30
SO_2 (a)	-50	-75	-80 to -90
NOx (a)	-10	-60	-70 to -80
NH_3 (a)	-33	-70	-80
Hydrocarbons	-20	-50	-70 to -80
CFC's	-100	-100	-100
Discharges to Rhine and North Sea	-50	-75	-75
Waste dumping	0	-50	-70 to -80
Noise (leading to serious nuisance) (b)	+50	0	-15
Odour (b)	+10	-50	-60

a) Relative to 1980.
b) The changes for noise and odour refer to percent changes in numbers of people experiencing nuisance.

<u>Source</u>: NEPP (1989).

Table 9

Costs of the Dutch emission scenarios

(Costs of the environmental scenario's I, II and III (a), in billions of 1985 guilders)

	1988	2010 I	2010 II	2010 III
Gross annual costs	8.3	16.0	26.3	55.8
Annual savings	--	--	--	20 (b)
Net annual costs	8.3	16.0	26.3	36.8
Idem as % GNP	1.9	2	3	4
Total investments in the period 1990-2010	--	100	200	350
Cumulative effect on real GNP	--	-1.3	-3.5	-4.2

a) See Table 8.

b) Savings in energy and raw materials; these dependent on the development of energy prices. If the sudden 1985 price drop of 40 percent were to be set aside, savings could amount to about Dfl. 30 billion.

Source: NEPP (1989).

Table 10

Importance of energy activities in the generation of air pollutants

Pollutant	Man-Made as % of total	Energy Activities as % of man-made	Contributions as % of total energy-related releases
SO2	45% (a)	90% (a)	. Coal combustion: 80% (b) . Oil combustion: 20% (b)
NOx	75% (a)	85%	. Transport: 51% (b) . Stationary sources: 49% (b)
CO	50% (a)	30-50% (a)	. Transport: 75% (b) . Stationary sources: 25% (b)
Lead	100% (a)	90% (b)	. Transport 80% (c) Combustion in stationary sources (including incineration): 20% (c)
PM	11.4% (a)	40% (b)	. Transport: 17% (b) . Electric utilities: 5% (b) . Wood combustion: 12% (b)
VOC	5% (b)	50% (b)	. Oil industry: 15% (b) . Gas industry: 10% (b) . Mobile sources: 75% (b)
Radionuclides	10% (a)	25% (a)	. Mining, milling of uranium: 25% (c) . Nuclear power stations and coal combustion: 75% (c)
CO_2	4% (a)	55-80% (a)	. Natural Gas: 19% (c) . Oil: 47% (c) . Coal: 34% (c)
N_2O	37-58% (a)	65-75% (a)	. Fossil fuel combustion: 60-75% (a) . Biomass burning: 25-40% (a)
CH4	60% (a)	15-40% (a)	. Natural gas losses: 20-40% (a) . Biomass burning: 30-50% (a)
CFC_3	100% (a)	10-30% (a)	. Refrigeration, air conditioning: 40% (a) . Insulation foam: 60% (a)

a) Global estimates.
b) Estimates for OECD countries.
c) Estimates for United States.
. Contribution of anthropogenic CO2 to <u>increases</u> in CO2 concentrations and to global warming is much larger.

<u>Sources</u>: IEA (1989).

Table 11

Energy requirements by source
(As a percentage of total energy requirements)

	Solid fuels		Oil		Gas		Nuclear Power		Hydro-, Geothermal and Solar Energy	
	1970	1987	1970	1987	1970	1987	1970	1987	1970	1987
North America	19.8	25.8	43.8	40.0	30.9	22.1	0.3	5.9	5.2	6.1
Japan	23.0	18.0	68.8	55.9	1.2	9.9	0.4	11.3	6.7	5.0
Australia	43.2	39.3	46.5	34.5	2.2	17.3	0.0	0.0	8.1	9.0
OECD Europe	28.0	21.9	58.1	43.5	6.2	16.1	1.0	11.0	6.7	7.5
OECD total	**23.2**	**24.1**	**50.7**	**42.6**	**19.6**	**18.8**	**0.5**	**8.0**	**5.9**	**6.6**
World	29.1	29.2	46.4	40.1	17.5	19.8	0.4	4.7	6.5	6.2

Source: OECD (1989).

Table 12

Worldwide CO_2 emissions from energy sources
(regional shares as per cent of worldwide emissions, GNP, population and energy requirements)

	Emissions			GNP	Population	Energy
	1971	1981	1987	1987 (a)	1987	1987
North America	30.1	26.6	24.9	32	6	28
OECD Europe	19.5	16.2	14.6	27	9	17
OECD Pacific	6.1	5.9	5.3	14	3	6
Total OECD	55.7	48.7	44.8	73	18	51
Centrally planned economies (b)	30.2	33.3	35.2	14	31	32
Africa	3.1	4.0	4.3	2	12	(
Latin America	4.3	5.1	5.3	5	8	(17
Asia (excluding CPE's and Japan)	6.7	8.9	10.3	6	31	(
Total (million tons)	4343	5430	6034			
Yearly per cent change	..	2.3	1.8			

a) The estimate of the worldwide GNP distribution is based on the sources below.
b) USSR, other Eastern European countries, China and North Korea.

<u>Source</u>: The World Bank (1989); PlanEcon Report (1989); OECD (1989).

Table 13

Impact of policies to limit CO_2 emissions

(Per cent deviations from reference case values)

	OECD	World
CO_2 emissions, 2005		
Nuclear policy (a)	-19	-7
Carbon tax (b)	-12	-4
Combined policy (c)	-25	-9
CO_2 concentration levels, 2050		
Combined policy (c)		-1.5 to -2.5

a) Increase in nuclear share in electricity production to 70 per cent in OECD countries.

b) Tax on carbon in OECD countries equal to 50 dollars per tonne coal equivalent.

c) The effect of a combined policy is less than the sum of the impacts of the two policies due to policy overlap.

Source: IEA (1990).

Table 14

Some international agreements and conventions on environmental protection

The ECE Convention on Long-range Transboundary Air Pollution:
Signed by 34 countries in November 1979, and entered into force in March 1983, having been ratified by 24 countries; to this convention was added:

-- The Helsinki Protocol, which was signed by 20 countries and entered into force in September 1987. In broad terms, the Helsinki Protocol states that the signatories reduce their national annual sulphur emissions or their transboundary fluxes by at least 30 per cent by 1993 at the latest (using 1980 emission levels as the base year);

-- A protocol on nitrogen oxides (NOx), which was signed by 25 countries in October 1988 in Sofia. This protocol will enter into force when ratified by 16 signatory countries. As a first step, the signatory countries agreed to take measures against further increases of NOx emissions so that national NOx emissions do not increase beyond 1987 levels after 1994.

The UNEP Convention for the Protection of the Ozone Layer:
Signed in Vienna in 1985; in 1987, the Montreal Protocol was added to this convention, in which signatory countries (46) agreed to halve their production of five chloro-fluorocarbons (CFCs) and three halons by 2000.

The UNEP Basel Treaty to control international trade in hazardous waste:
Signed in March 1989 by 34 countries and the EEC; the signatories agree in principle to ban and establish notification procedures for all trade in hazardous waste.

Conventions to protect the marine environment include:

-- The 1972 London Agreement on Prevention of Marine Pollution from Dumping of Waste and Other Materials;

-- The 1974 Paris Convention for the Prevention of Marine Pollution from Land-based sources;

-- Conventions regulating the use of regional seas (UNEP regional seas programme), such as the 1976 Barcelona Convention in which the 16 signatory countries agreed to the Mediterranean Action Plan, the 1974 Helsinki Convention on the Protection of the Marine Environment of the Baltic Sea Area (7 countries) and the 1987 London Ministerial Declaration on the protection of the North Sea (8 countries).

Other international agreements on resource preservation include the Law of the Sea (1982; 160 signatories), agreements on whaling, wetlands and migratory birds, Antarctica and the trade in tropical timber. UNEP (1989) lists altogether 140 various international agreements, conventions and protocols.

Source: ECE (1989).

Chart A.

Abatement cost and damage function

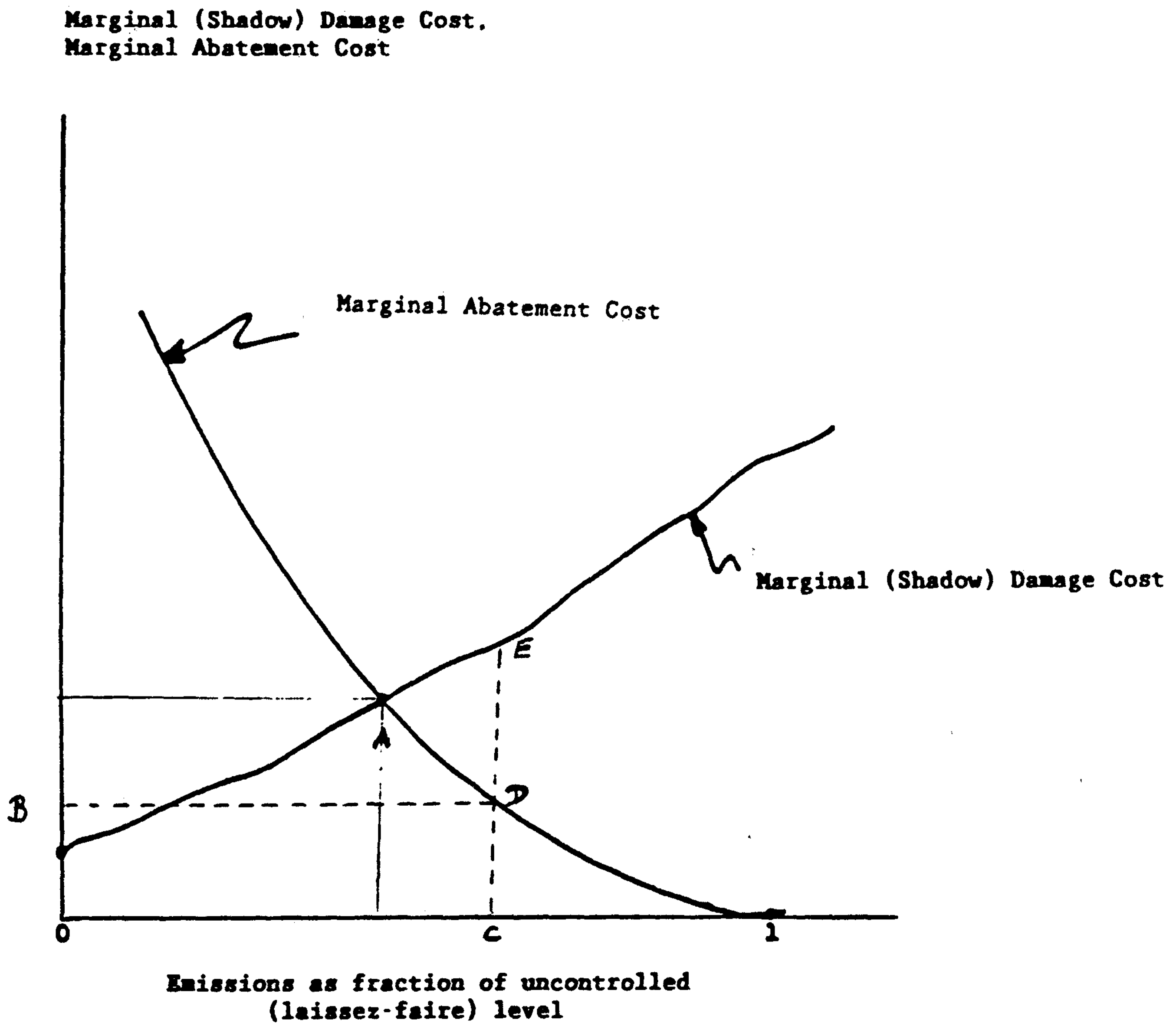
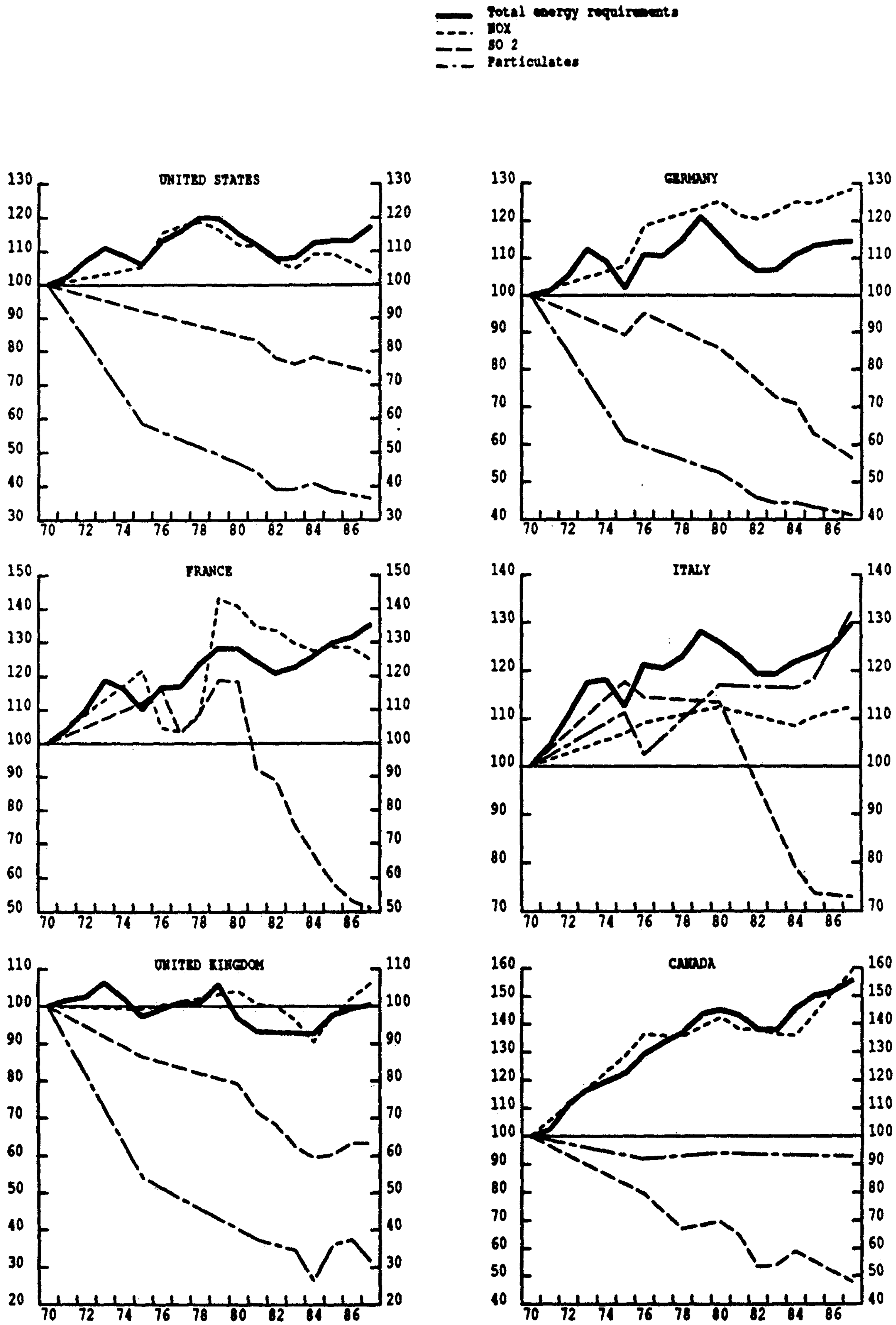


Chart B.

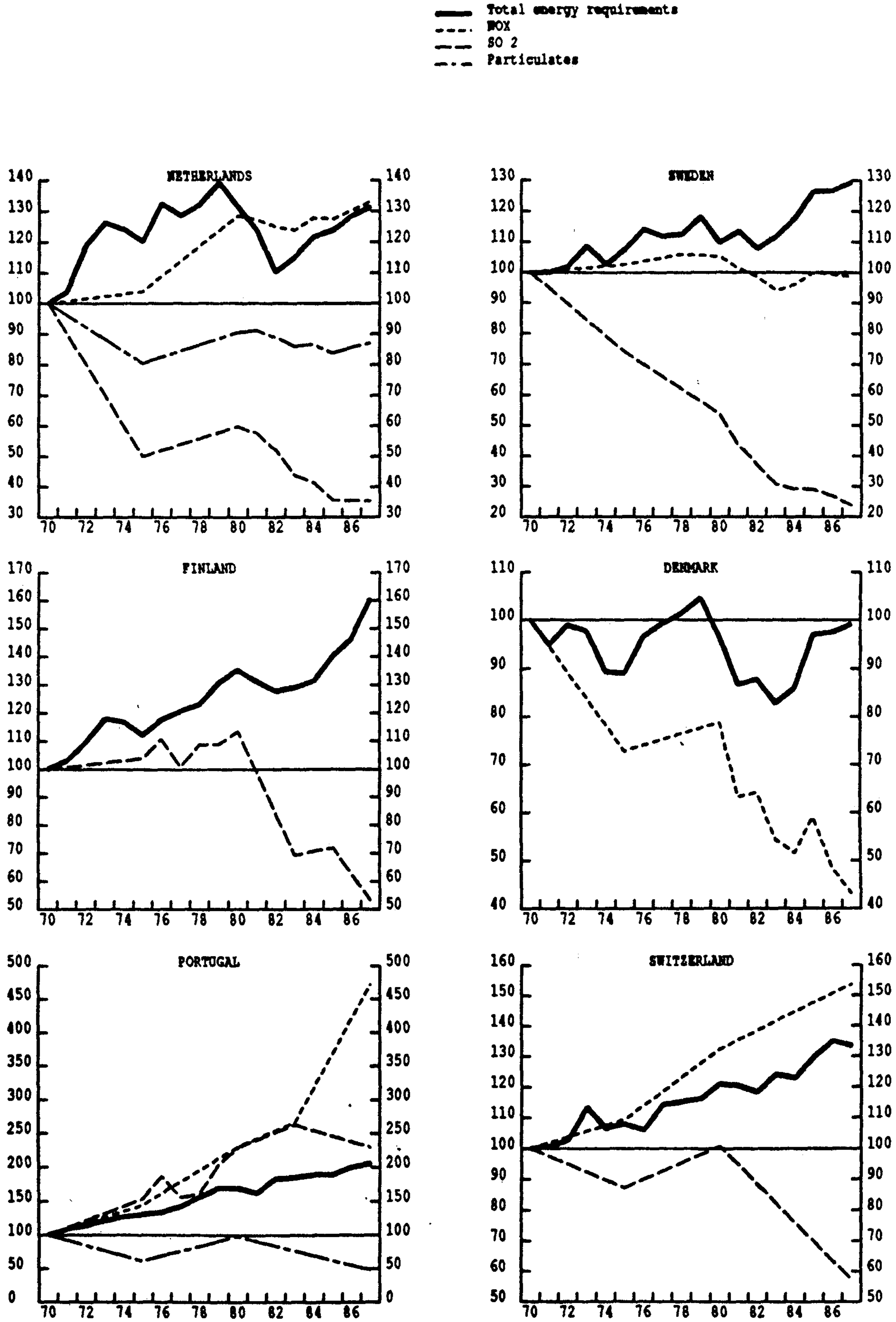
Emissions of air pollutants by country



<u>Source</u>: OECD, (1989).

Chart B.

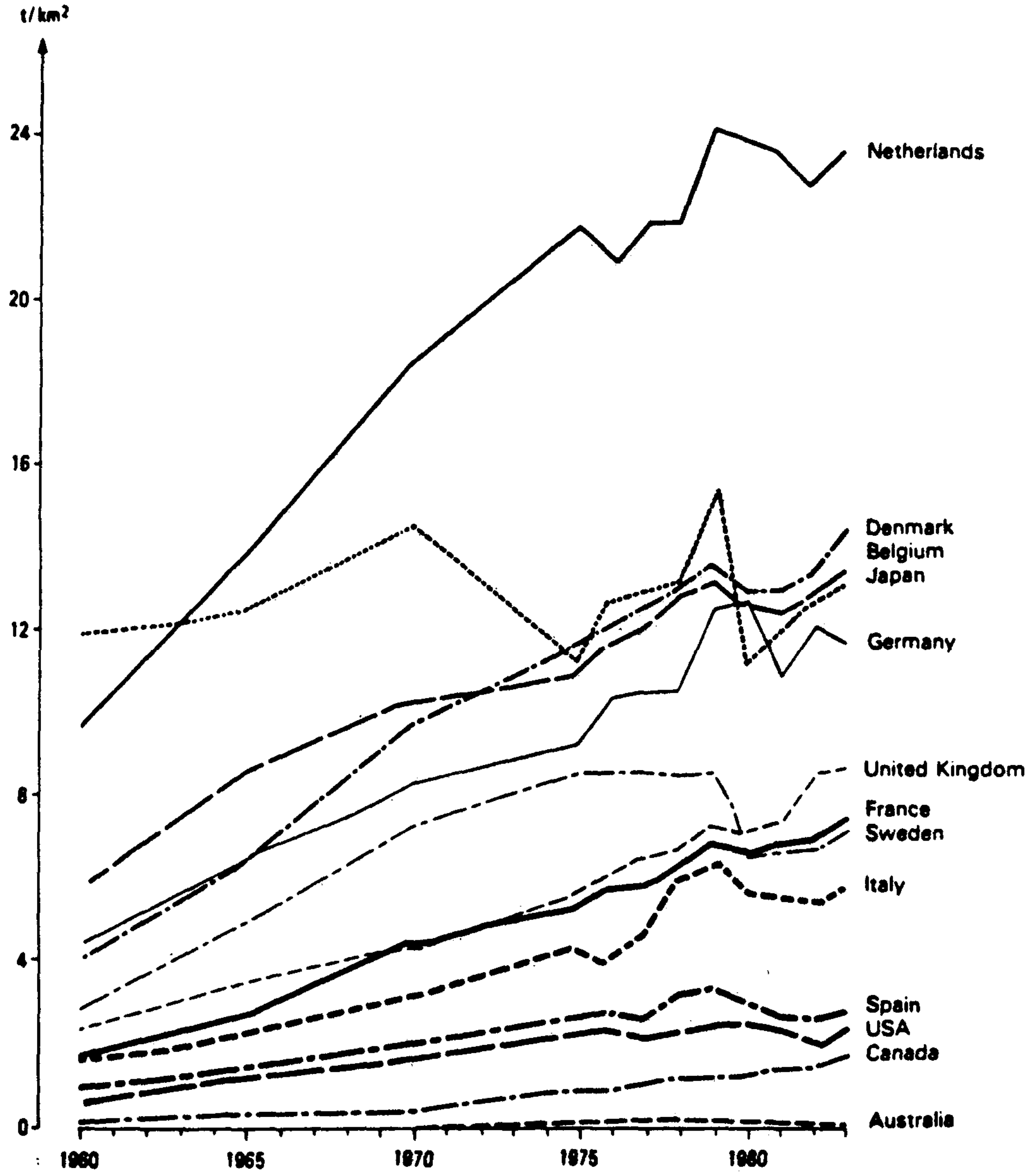
Emissions of air pollutants by country (continued)



Source: OECD. (1989).

Chart C.

Application of nitrogenous fertilisers (a)



a) In tonnes per km^2 of agricultural land.

<u>Source</u>: OECD (1985).

Chart D.

Rising nitrate levels in groundwater in Denmark

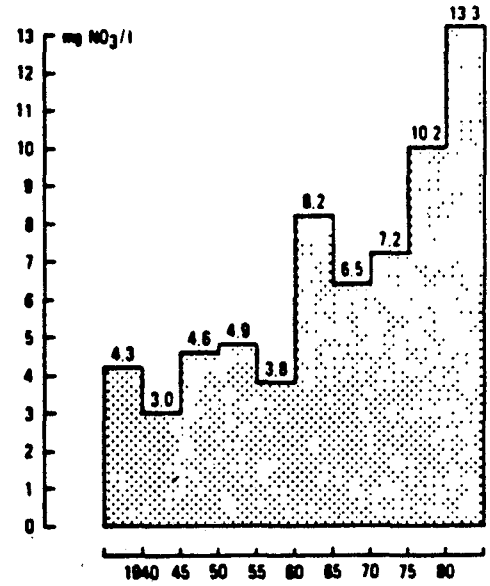
A Long-Term Trend of Rising Nitrate Levels

Rising nitrate levels in groundwaters represent a general trend in most OECD countries. Excessive intake of nitrates can have consequences for human health, especially for bottle-fed babies. A limit has therefore been established by the EEC of 50 milligrams of nitrate per litre (mg/l) of potable water, with a recommendation of below 25 mg/l for water given to babies.

In Denmark the National Agency of Environmental Protection has carried out a nation wide survey of nitrate levels in potable water supplies and in groundwater. The survey includes 15 000 analyses of nitrate concentrations in groundwater and covers 99 per cent of the potable water which is supplied from waterworks. It allows trends to be identified over several decades.

The results show that nitrate levels in Danish groundwater have increased three-fold on average, from 4 mg/l to 13 mg/l, during the last 30 years. Nonetheless, most groundwater in Denmark either is still free of nitrates or has only a negligible concentration. Sixty-nine per cent of all groundwater analyses showed nitrate levels below 5 mg/l while 14 per cent had concentrations above the recommended value of 25 mg/l and 5 per cent exceeded the 50 mg/l limit. For the population as a whole, this means that approximately 700 000 inhabitants are supplied with water in which the recommended value is exceeded, and approximately 350 000 inhabitants receive water with a nitrate concentration over the 50 mg/l limit. The worst cases are found in Jutland.

NITRATE LEVELS IN GROUNDWATER
IN DENMARK
(AVERAGE VALUES FOR 5-YEAR PERIODS)



The Causes of Rising Nitrate Levels

A study undertaken by the National Agency of Environment with the assistance of the Ministry of Agriculture, completed in 1984, concluded inter alia that the agricultural sector is by far the most important source of the nitrates leached into groundwater in Denmark.

The total amount of nitrogen used in agriculture has doubled during the last 25 years; this in itself, though, was found not to be the main reason for the observed trends in groundwater quality. The study found that the increased nitrate leaching was partly caused by the trend towards more intensive livestock farming. This leads to an overproduction of animal fertilizers (manure, pig slurry, etc.) in relation to the crop acreage of the individual farms. Not all of the fertilizer can be utilised by the crops, therefore, and leaching results. Furthermore, because of capacity problems in manure heaps and slurry tanks, animal fertilizers are often spread on the fields in the autumn when there are no crops growing to utilise them. Nitrate leaching was thus found to be mainly a consequence of the inappropriate storage and use of animal fertilizers.

Proposals for Counter-Measures

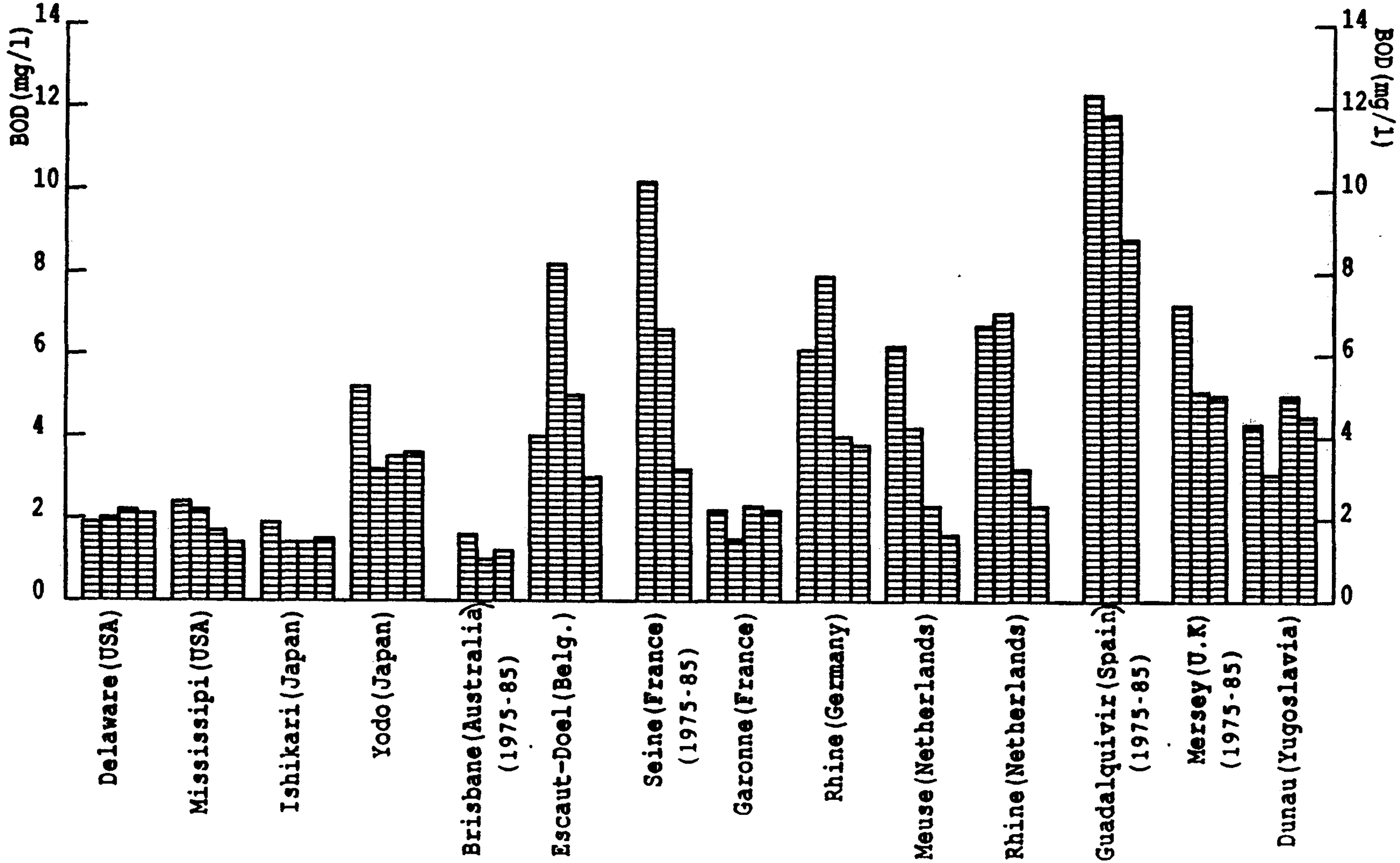
The study's main proposals are that all livestock farms should have a storage capacity for animal fertilizers of up to one year, so that the fertilizer can be spread in the spring when the crops can utilise it. Furthermore, there should be limitations on the number of head of livestock relative to the crop acreage, and sub-standard installations should be improved. It is estimated that the adoption of these counter-measures will reduce nitrate leaching by more than 35 per cent.

The cost of establishing this storage capacity is estimated to be DKr 7 billion ($780 million), or about DKr 560 million ($62 million) in annual capital costs. The resulting annual savings on chemical fertilizers, through improved utilisation of animal fertilizers, are estimated to be at least DKr 250 million ($28 million): that is, about half of the capital costs. Further studies have indicated that utilisation of the animal fertilizer that at present is lost from sub-standard storage installations will save another DKr 335 million ($37 million) per year.

Source: OECD, (1985).

CHART E

Water quality of selected rivers (a)

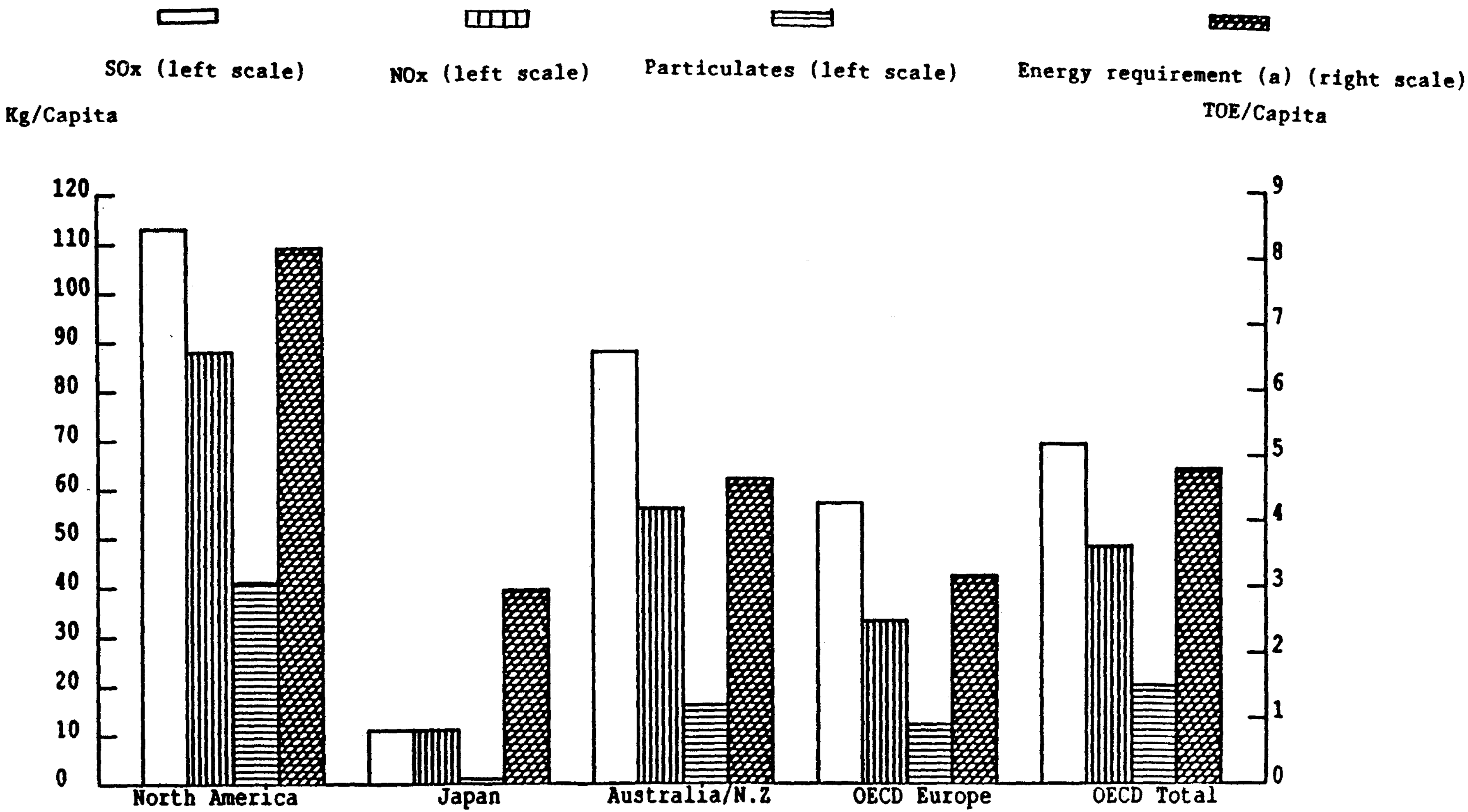


a) Biological oxygen demand, (BOD) at mouth or downstream frontier in 1970, 1975, 1980, 1985.
High BOD indicates low water quality.

Source: OECD (1989)

Chart F.

Air pollution and energy use per capita



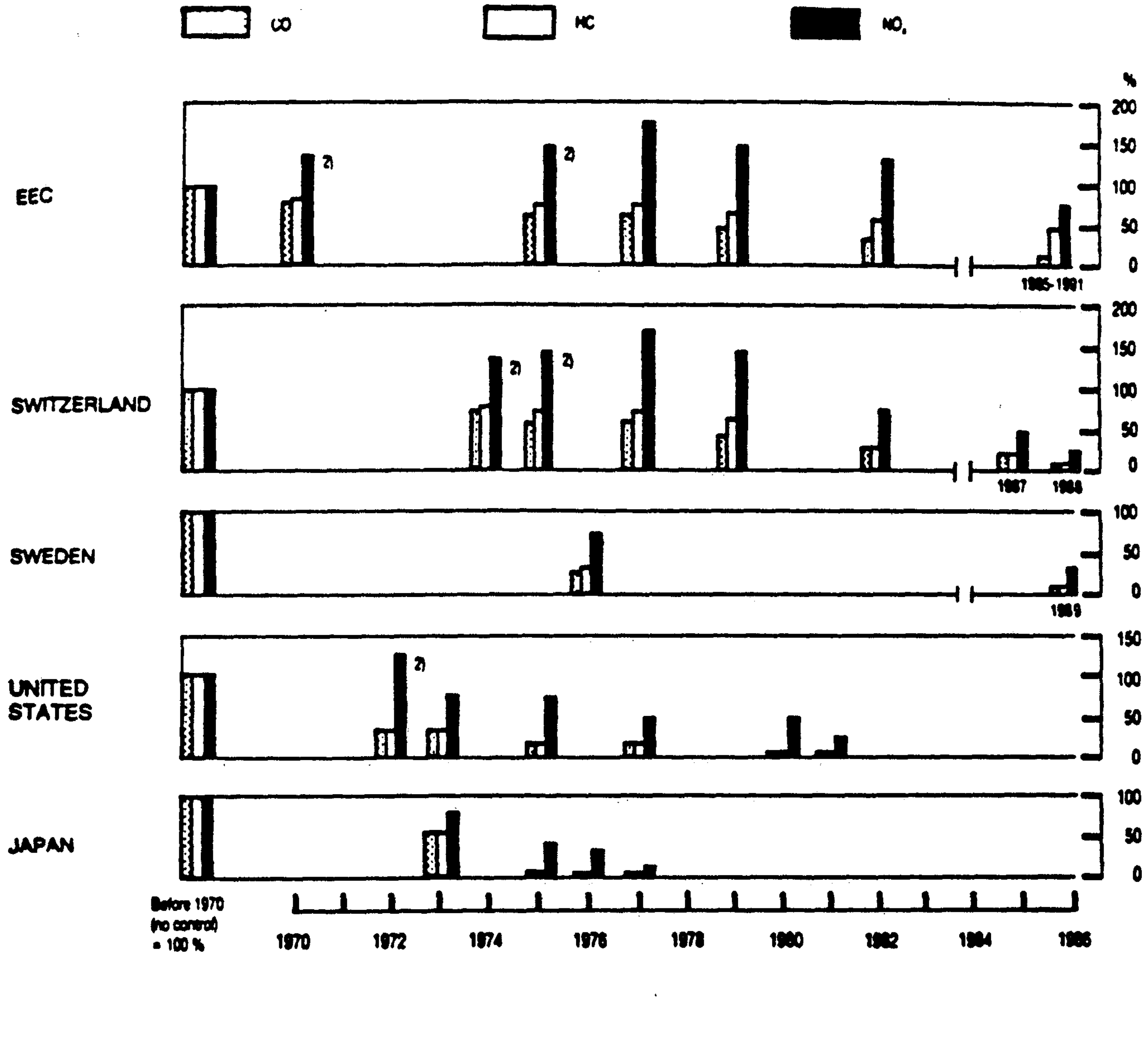
(a) Measured in tons of oil equivalent (TOE)

<u>Source</u>: OECD, (1989).

Chart G.

Trends in standards on automobile exhaust emissions (1)

(Gasoline Powered)



1. Data are not comparable since pre-1970 reference cars were different in levels of pollution and weight across countries.
2. Increase in NO_x due to the absence of regulation.

Source: ECMT (1989).

Chart H

Material flows, fuels and pollution

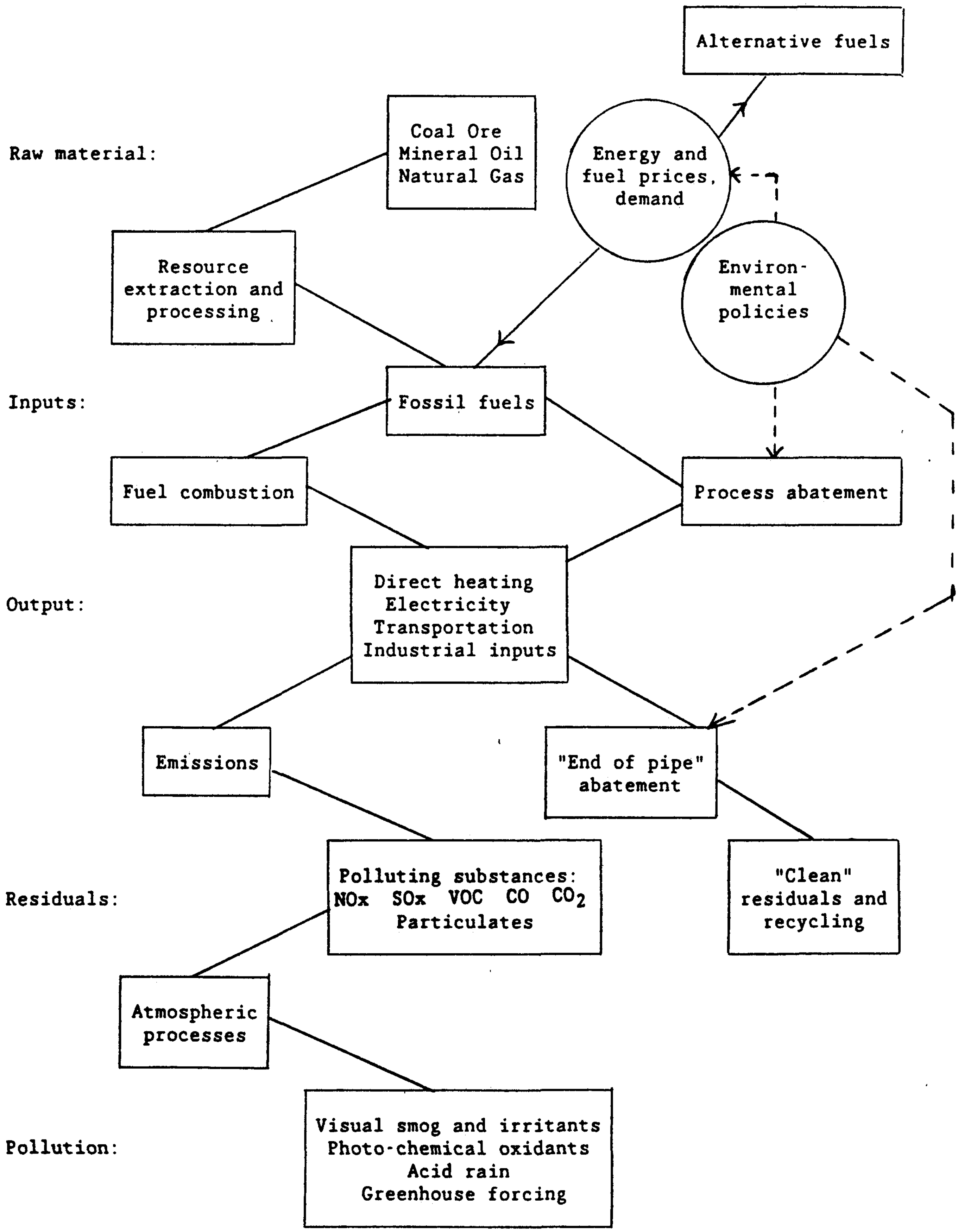
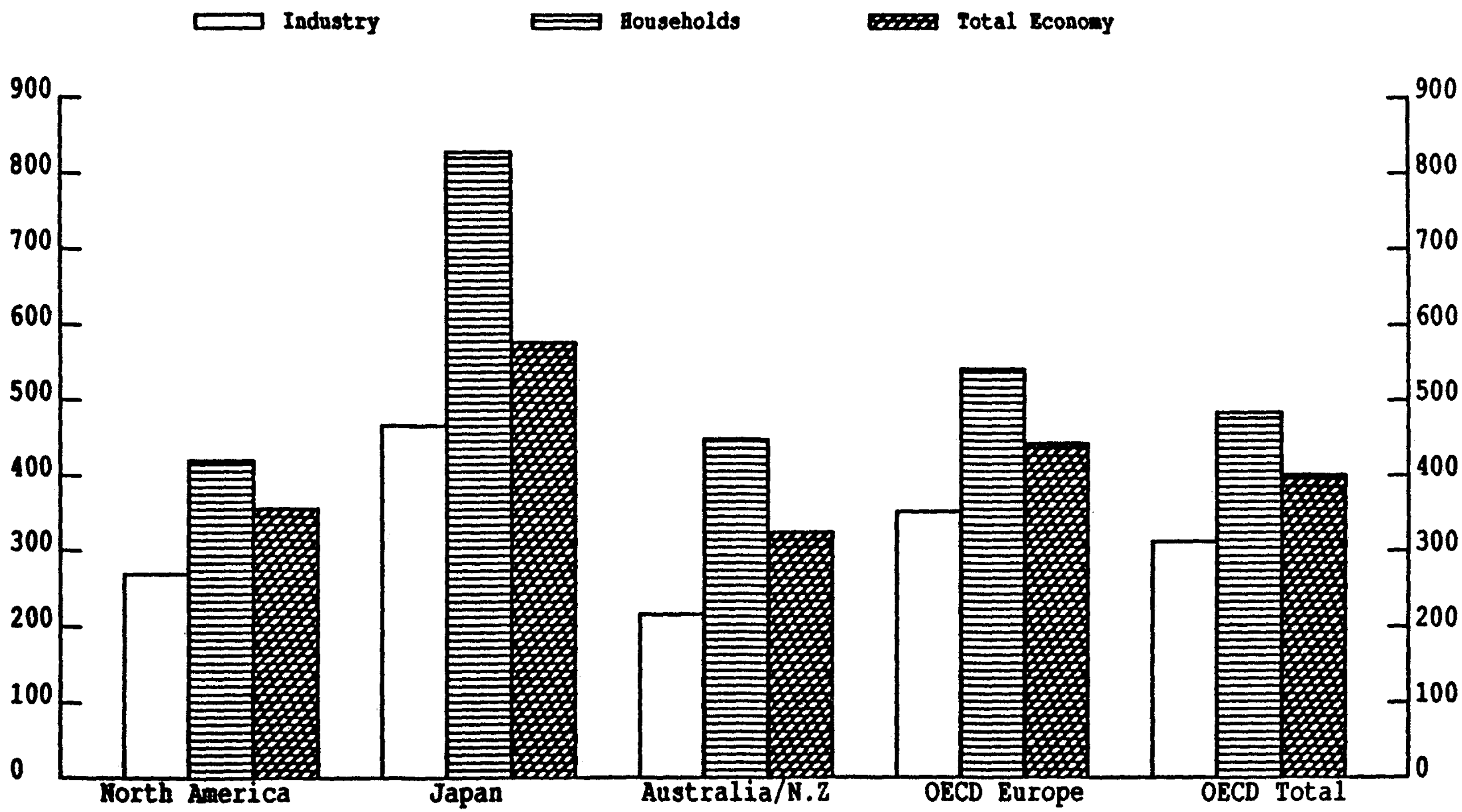


CHART I

Average energy prices per TOE (1)
($ US, 1985)



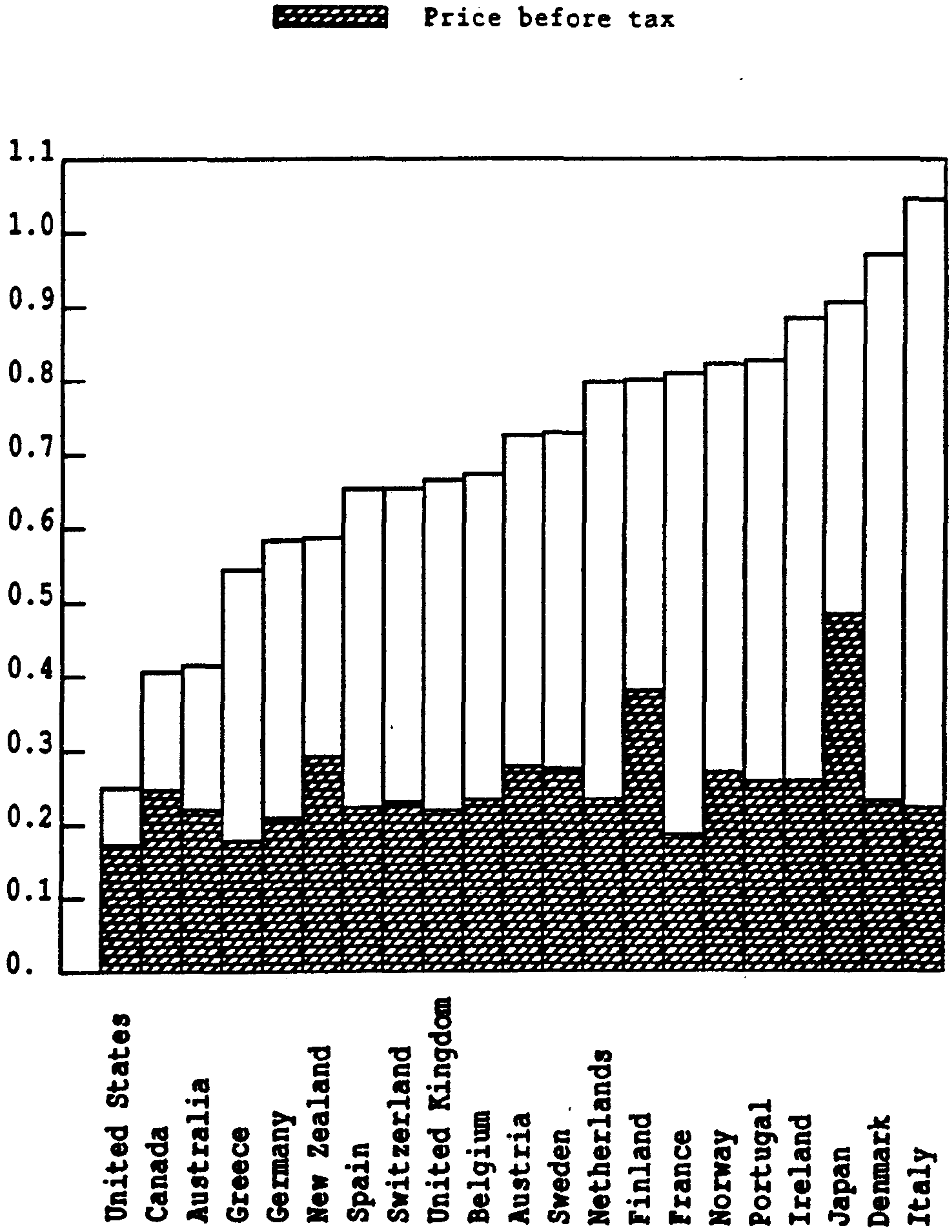
1) Ton of oil equivalent.

Source: IEA (1989 b)

Chart J

Gasoline prices and taxes

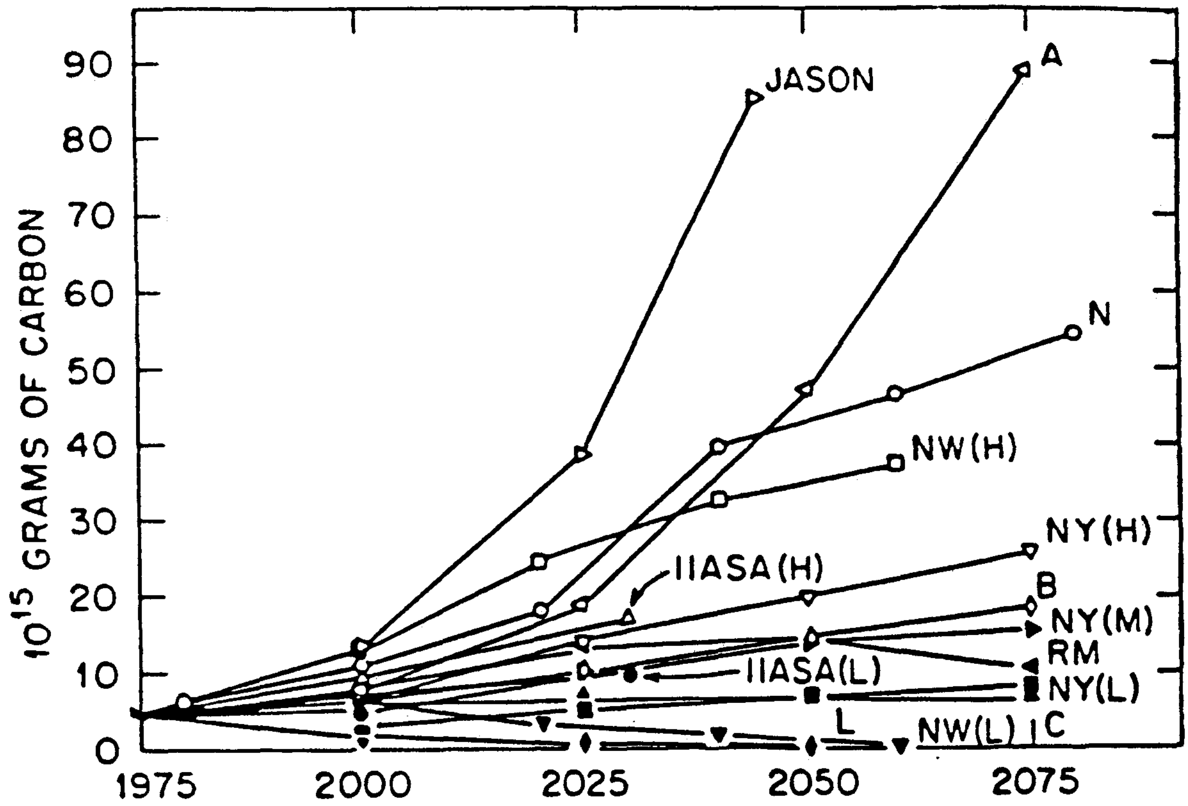
(US Dollars/litre, 1988)



Source: IEA, (1989b).

Chart K

Long-run CO_2 emission scenarios



Key:

A B C	Case A) Case B) Edmonds and Reilly (1983) Case C)
N	Nordhaus (1979)
NW(H), NY(M), NW(L)	Niehaus and Williams (1979) H = high case (50-TW - fossil fuel scenario) L = low case (30-TW - solar-nuclear scenario)
NY(H), NY(M) NY(L)	Nordhaus and Yohe (1983) M = mean case H = mean case plus one standard deviation L = mean case less one standard deviation
IIASA(H), IIASA(L)	Hafele (1961)
RM	Rotty and Marland (1980)
JASON	JASON (1979)
L	Lovins et al (1981)

Source: Environmental Resources Limited (1989).

Chart L

Contributions to the greenhouse effect

The Greenhouse Gases

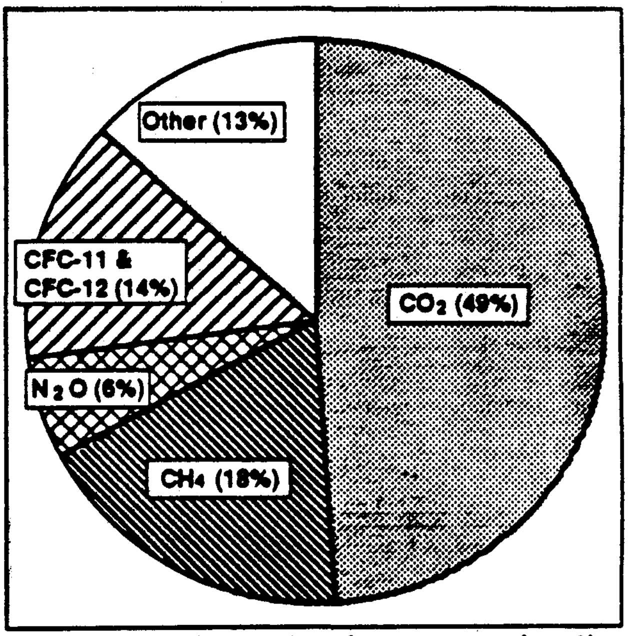
The climate warming potential of different greenhouse gases depends upon the properties of the gases and changes in their atmospheric concentrations. Carbon dioxide (CO_2) is currently the most significant greenhouse gas, responsible for about half of current increases in the greenhouse effect, but many other gases contribute to global warming -- chlorofluorocarbons (CFCs), methane (CH_4), nitrous oxide (N_2O). The figure below shows the relative contribution of each gas in the 1980s.

Carbon Dioxide (CO_2) is increasing at about 0.4% per year, primarily due to fossil fuel combustion and deforestation.

Methane (CH_4) is increasing at about 1% per year. Sources include rice production, enteric fermentation in domestic animals, biomass burning, fossil fuel production, and anaerobic decomposition in landfills.

Nitrous Oxide (N_2O) is increasing at about 0.25% per year, as a result of nitrogenous fertilizer use, land clearing, biomass burning, and fossil fuel combustion.

Chlorofluorocarbons (CFC's) have increased very rapidly this decade (about 5% per year). CFC's are synthetic chemical compounds.

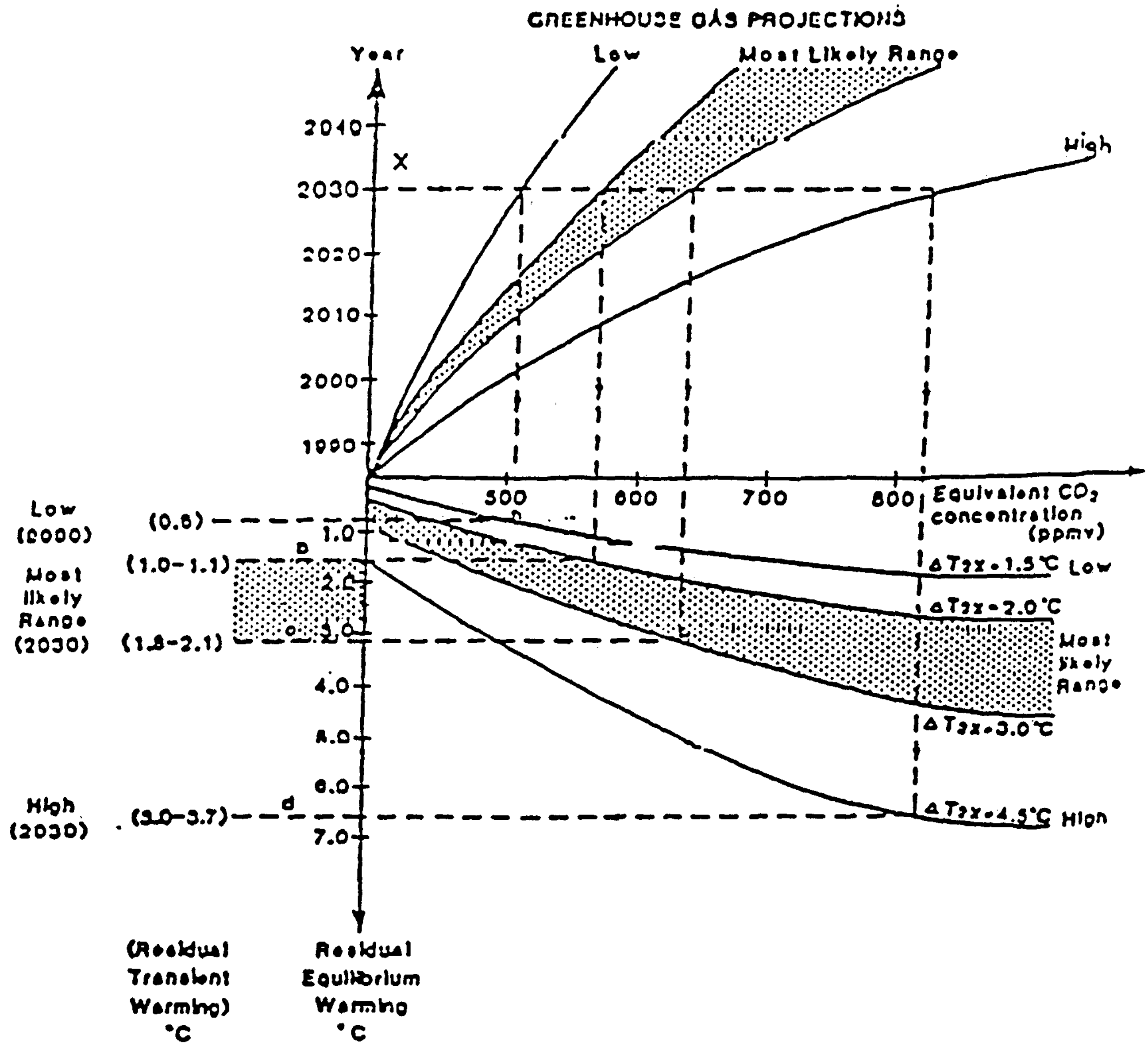


Contributions to Increases in the Greenhouse Effect During the 1980s. Estimated values based on concentration changes.

Source: EPA, (1989).

Chart M

Climate change scenarios



Source: Pearce (1989a).

Chart N

A "Pay-off Matrix" for approaches to environmental uncertainty

TYPE OF POLICY		Actual State of the World	
		Optimists Right	Pessimists Right
	Optimistic	HIGH	DISASTER
	Pessimistic	MODERATE	TOLERABLE

The pay-off matrix suggests that if the technological optimists are right and a policy of relative indifference to the environment is pursued, then society might make high gains. If the optimistic policy is pursued and the pessimists turn out to be right then some form of "disaster" might occur. Pursuit of "prudent pessimism" on the other hand results in moderate gains or, at worst, tolerable gains. The terminology is sugggestive only, of course. Substituting "nirvana" for "high" might alter the perception of the matrix a little. Nonetheless, the basic idea of seeing what happens if a given policy is pursued, when in fact the state of the world is not consistent with that policy, is correct.

The matrix is adapted from Robert Constanza, "What is Ecological Economics?" Ecological Economics, Vol. 1, No. 1, 1989, pp. 1-7.

Source: Pearce, (1989a).

6.7.90

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In April 1983, the Economics and Statistics Department initiated a new series of economic studies entitled ESD Working Papers.

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   Substitution du capital, de l'énergie et du travail : le bloc de l'offre dans les modèles à moyen terme de l'OCDE (épuisé)

   Patrick Artus

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Stratégie financière à moyen terme : la coordination des politiques monétaire et budgétaire (épuisé)

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La politique monétaire dans le modèle INTERLINK

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Produit brut réel et parités de pouvoir d'achat dans les pays de l'OCDE (épuisé)

Peter Hill

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Prof. Edward Gramlich, University of Michigan

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