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ANNEX 9

TO MINUTES OF THE OSLO MEETING

ENERGY, ENVIRONMENT AND DEVELOPMENT

ACID RAIN
NOTE BY THE SECRETARY GENERAL
(WCED/85/16)

BACKGROUND PAPER ON ACID RAIN
(WCED/85/16 Add 1)

and

RESUME OF REMARKS BY COMMISSIONER HAUFF

WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT

THIRD MEETING
Oslo, 21-28 June 1985

WCED/85/16

Item 6.1 of the Provisional Agenda

ACID RAIN

Note by the Secretary General

ACID RAIN

Note by the Secretary General

1. The Commission will commence its consideration of the energy-related environment and development issues in Oslo, beginning with the critical question of acid rain. To that end, Commissioners have received a background paper on acid rain prepared by Dr Ian Torrens. The paper focusses naturally on the situation in Europe and North America: that is where the issue has evolved, where the evidence is, where it has climbed to the top of the political agenda. Balanced, the paper includes a brief review of the findings of all of the major recent reports on the key scientific and policy questions. Comprehensive, it sets out much of what we know about acid rain sources and effects, policy concerns, technologies, economics, control and prevention strategies.

2. But evidence underlying the urgent need for action on the sources of acid rain is mounting with a rapidity that exceeds the capacity of scientists and governments to assess it. Some recent evidence is particularly disquieting. It concerns forest die-back stemming from direct conifer-needle damage and soil acidification which accumulates over time and, beyond a certain point, causes the insoluble aluminium present in the soil to pass into solution. In this form it is highly toxic to plants and may render the soil incapable of supporting tree growth.

3. If this is true, we may be witnessing in Europe an immense, regional acid-base chemical titration with potentially disastrous results being signalled by widespread tree damage and death, in effect, a kind of "environmental litmus paper", indicating a change to irreversible acidification whose remedial costs are beyond economic reach. Comparatively speaking, forest death on a regional scale would be socially and economically trivial compared to such consequences as erosion, siltation, flooding of farmlands and towns and local climatic change.

4. There was little evidence of tree damage in Europe in 1970. In 1983, FRG reported clearly visible damage to 34 percent of its trees; in 1984, to 50 percent. Have European soils reached a trip-over point? What is the evidence?

5. Professor Gordon Goodman, our Special Adviser on Energy, has been following this from his special vantage point at the Beijer Institute. I have asked him to prepare a paper on this evidence and its possible consequences, and to be present in Oslo, along with Ian Torrens, to discuss the entire issue with you. 1).

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1) The Commission will also be receiving paper(s) on acid rain during the Public Hearing in Oslo.

6. Acid rain is becoming a serious concern in other regions, but in the absence of monitoring and assessment programmes, very little hard evidence is available. We have requested papers on China, Japan and tropical countries, and the results will be available to the Commission in due course, probably via the Energy Panel.

7. The Commission will wish to consider acid rain from the perspective of the year 2000 and beyond, focussing on strategic options now available to Europe and North America to reduce or adjust to the high-cost scenario now evolving and the options available to other regions to prevent a repeat of this scenario. It will also want to consider acid rain in the context of other fossil-fuel related issues, especially air pollution and climatic change induced by rising levels of CO_2.[2] Strategies for the one re-inforce strategies for the other.

8. Moreover, during the course of its work, the Commission will want to examine all of these issues, beginning with acid rain, from a <u>source</u> rather than an <u>effects</u> perspective. Here the papers by Goodman and Torrens provide an excellent point of departure, with a number of options set out clearly. For purpose of easy reference, I would set out the options contained in their papers as follows:

1) <u>Reduce Future Emissions</u>

- strengthen energy efficiency measures;
- use lower sulphur fuels and fuel cleaning;
- promote renewable energy sources;
- extend post-combustion cleaning of exhaust gases.

2) <u>Strengthen Institutional Links and Co-operation</u>

- develop maps of areas environmentally sensitive to acid deposition;
- establish national acidification units including representatives of all agencies concerned;
- include representatives of energy agencies/industries in environmental planning, assessment, implementation and monitoring bodies; and vice versa;

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2) We have requested papers to bring together the evidence on air pollution in South East Asia, India, Latin America, FRG, Japan and USA. We have also requested a major paper on Climatic Change: the Strategic Options to follow this autumn's meeting of the International Co-ordinating Committee on CO_2. In the meantime, the Commission will receive at least one major brief on Climatic Change at the Public Hearing in Oslo.

- ditto for boards responsible for policy concerning energy, R & D and investment projects;
- joint initiatives to promote energy efficiency.

3) Strengthen Economic Incentives and Dis-incentives

- integrate environmental costs in energy prices; and consider
- incentives (tax credits, grants, etc) for environmentally favourable energy investments;
- emission goals, licences and flexible trading in licences;
- deposits by potential polluters, (refundable upon proof of acceptable behaviour);
- effluent charges;
- inflation-proof fines for non-compliance.

4) Improve Regulatory Measures

- new source standards; e.g.
  - ambient quality standards;
  - Europe-wide emission standards;
  - fuel efficient product design and input standards;

- old source standards;
- zoning and licensing of polluting activities, including provision for emission goals, abatement deposits, flexible trading, etc.

5) Improve the Information Base for Management

- strengthen emission-transport-deposition monitoring in Europe and North America;
- extend such monitoring urgently to newly industrializing countries and tropical regions;
- identify soil/forest/water sensitive areas, especially in the newly industrializing countries and tropical regions;
- increase economic evaluation of present and future damage costs.

6) Strengthen International Co-operation

- strengthen institutional linkages on regional basis (see above);
- establish preventive co-operation programmes in critical newly industrializing and tropical regions;
- undertake urgent programmes to increase the information base (see above), with the support of multilateral and bilateral assistance agencies;
- provide advisory services on preventive policies.

ACIDIFICATION OF THE ENVIRONMENT[1/]

A policy Ideas Paper by Gordon T. Goodman,
Special Advisor on Energy, Environment and Development
to
World Commission on Environment and Development

INTRODUCTION

This draft-paper is intended as a starting-point, raising policy issues and options for managing this problem, currently very important in industrialized regions and potentially harmful to newly industrializing developing countries.

It outlines what is generally agreed as "known for certain" about the whole problem and conversely, what is still argued about strongly among "net emitter" and "net receiver" governments. It is perhaps only natural that many major emitters of acid gases from their own industrial sources claim that, "the problem may not exist", or "it is not serious", or that anyhow, "we do not know enough about the problem to manage it effectively - more research is needed". And equally so, net receivers of acid deposition claim the opposite.

This is almost certainly why the opinions of "government scientists" still differ widely, nation by nation on this issue, whilst there is a growing consensus about industrial acid-emission-causes and environmental-deposition-effects among the international scientific community as a whole.

A few ideas for policy proposals are very tentatively put forward here, for consideration by the Commission Meeting in Oslo, as a starter to stimulate reaction and discussion for the subsequent building up of a considered attitute and response to this major issue.

This draft is not an official Secretariat paper. Although the author has greatly benefitted from critical discussions with the Secretariat on its substance, final responsibility for any erroneous views rests solely with the author.

1/ Further details and full references in this draft can be obtained in the Background Issue Paper "Acid Rain and Air Pollution a Problem of Industrialization" by Ian M. Torrens, June 1985

ACIDIFICATION OF THE ENVIRONMENT

A policy ideas paper by Gordon T. Goodman,
Special Adviser on Energy, Environment and Development
to
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SUMMARY

Emissions to the atmosphere of oxides of sulphur and nitrogen (SO_x & NO_x) and volatile hydrocarbons (from industrial, domestic and vehicular sources burning coal, oil and gas) and their transformation products during atmospheric transport (sulphuric and nitric acids, their ammonium salts, ozone) fall to the ground as dry particles or in rain, snow, frost, fog or dew. Deposition may occur several thousands of kilometres from their emission sites after the acidifying or oxidizing substances have been windborne for a few days.

They corrode stonework and rust or rot metal structures, causing USD billions of damage costs annually. They also damage trees, soils, lakewaters, rivers and fish and may enter the drinking water supply, corroding pipes or liberating potentially toxic metals (cadmium, lead, mercury, zinc, copper, aluminium, possible future risks to human health or toxic to tree roots).

Up to now, the greatest damage has been reported over East and West Europe which is currently receiving more than 1g sulphur per m^2 ground per year. Visible damage has been recently recorded in 50 per cent of forest lands in the Federal Republic of Germany and light to moderate damage in 30 per cent of Swedish forests. So far an estimated 5-6 per cent of all European forest land is affected. Many reports consistently show soils in parts of Europe becoming acid throughout the tree rooting layers (c. 100 cm deep). The acidity is frequently below PH 4.0 and aluminium comes into solution as a mobile element, toxic in very low concentrations to plant roots. The tree damages caused by the co-action of acid soils containing mobile aluminium and by direct needle damage in conifers from the interaction of the pollutants mentioned above.

Several thousand Scandinavian lakes are now acidified and a large number of them are fishless. Similar damage is appearing in North America and as industrialization spreads to other world regions, newly industrializing developing countries will be at risk.

Although governments and industry in North America and several European countries are already spending considerable sums of money on emission control technology and other clean-up strategies, this does not appear to be adequate judging from the continuing environmental damage in Europe. Large sums of money are already being spent on liming lakes in Scandinavia in an attempt to neutralize the acidity. If acid deposition continues, more lakes will be rendered fishless and forest

soils become more widely acid as their acid neutralizing capacity is slowly used up. The largest uncertainty hangs over the fate of European forests. If they finally die-back over large areas they will probably be replaced naturally by acidic grasslands and heather moorland, nowadays of little or no agricultural value. Soil erosion is likely to become a growing problem especially in hilly areas: siltation, flooding and water shortages are the classical corollaries of widespread deforestation. Absolutely minimal costs of liming even the most easily treatable land will be in excess of USD 500 per hectare.

By contrast "off the shelf" technology exists to achieve 80-90 per cent reductions in emissions at costs which, though not insignificant, are nevertheless very far from crippling. For instance several countries have calculated that 50 per cent sulphur reductions in the electricity generation process using coal can be achieved at a cost of under 6 per cent to the consumer.

The major uncertainty hinges on whether the forests will finally deteriorate to the point of environmental crisis when soil liming on such a scale will be beyond economic reach. Or whether to hope they will find a new equilibrium which although of degraded yield productivity, still remains adequate to hold soil and groundwater under normal control.

The newly industrializing countries will in future most probably need to depend more heavily on fossil fuels for accelerated development. So little is known about the likely environmental loading of sulphur and nitrogen and virtually nothing is known about the acid neutralizing capacity of tropical lakes and forest soils that a comprehensive programme of investigation should be formulated without delay if the mistakes made in Europe and North America are not to be repeated.

Returning to Europe, the balance of current evidence seems to indicate that it would now be prudent for governments to implement accelerated source-control actions, preferably under the co-ordination on UNECE who are already co-ordinating excellent management initiatives as the agent of European governments. In this regard, some policy ideas are put forward as tentative proposals for the Commission to react to and build on in developing a policy position on this important problem.

Apart from some tentative proposals contained herein, there are some fundamental issues raised by the acidification problem which will confront the Commission when it deals with other problem areas also, e.g.:

The methodology of scientific proof requires a high degree of vigorous evidence before any new situation is built into the body of scientific knowledge (even in science, absolute proof is never possible). By contrast, political and management decisions are nearly always made under conditions of imperfect or uncertain knowledge. This is necessary because the costs of not making a decision often outweigh the costs of making a wrong one. Waiting for better evidence on a problem may mean that it is too late (perhaps disastrously so) to do anything about it. Governments are sometimes happy to use the excuse of needing scientific "proof" before acting when it suits them and government scientists may be readily able to tell their political masters exactly what they want to hear. A more structured approach is needed to this problem which can be agreed to by governments.

Tall chimney stacks were originally built in the constructive belief that the acid gases from fossil fuel combustion would be diluted, dissipated and finally assimilated by the environment. We now know this is not true and so *de facto* all countries dump air pollutants on their neighbour, although this was not originally intended. What right have they got to do so? There are no laws about it and yet it is obviously uncivilized behaviour, in extreme cases amounting to an unfriendly act.

This is another example of the environment as an issue of national security.

ACIDIFICATION OF THE ENVIRONMENT

POLICY PAPER

PART I- THE PROBLEMATIQUE

1. The origins of Acidifying Substances

Small percentages (usually less than 5) of sulphur and nitrogen, present in coals, oil, gas and peat, produce on burning, the gases sulphur dioxide(and some sulphur trioxide), nitric oxide (and some nitrogen dioxide). These are conventionally known as SO_x (SO_2+ SO_3) and NO_x (NO +NO_2).

Almost two thirds of the sulphur is generated by the electric power industry where coal is the main fuel, but oil when used, normally emits about the same amount of sulphur per unit of electricity produced. The remaining sulphur comes from industrial processes and metal smelters, and also from domestic space heating using principally coal but some oil. A global total of around 100 million tonnes is emitted annually- about the same order as that given off by purely natural processes e.g. volcanoes and decaying plants and animals.The amount of nitrogen in the form of NO_x is somewhere around this figure, over half coming from vehicle exhausts and most of the remainder, about equally, from gas used in industry and coal in electricity production. However in industrialized regions such as Europe, or eastern North America, the concentrations of man-made emissions of SO_x and NO_x are 10-20 times greater than the natural background.

Although quite a lot of these emitted gases fall to the ground close to their sources, very large proportions are carried by winds up to 2000 km or so away from their origins, particularly when emitted from tall chimney stacks (up to 300 metres high). During this process of transport which usually lasts 1-5 days, the NO_x and SO_x are converted into a number of acid, corrosive or oxidizing substances by a series of complex chemical reactions some of which are energized by ultra-violet light from sunshine. Sulphuric and nitric acids and their ammonium salts, ozone and peroxyacetylnitrates are formed. These either sediment out of the air as 'dry' particles or are 'wet' deposited in rain, snow, frost, fog or dew. There is general and good international agreement on the origins, transport and deposition of the NO_x and SO_x derivatives summarized above

2. Main Effects of Acidification

There is also general agreement that they corrode and destroy stonework, statues etc. and rust or rot metal structures - damage costing billions of US dollars to replace each year. Many buildings and monuments of great cultural value are not being repaired because of high costs.

There is however very strong international disagreement between emitting agencies and the net receivers of damage when other types of harm are involved, principally damage across national boundaries.

These are: the die-back and death of vegetation especially trees; the acidification of soils; lakes and rivers and damage to their soil-decomposer systems; the death of fish and loss of fisheries and possible indirect effects on the health of livestock and humans.

2.1 Effects in Newly Industrializing Countries (NICs).

Up to the present time, acidification damage has been reported widely from Europe and North America, but as industrialization spreads to other world regions, it is anticipated that severe effects will occur in them unless preventive strategies are implemented as early as possible to head off the problem. The group of NICs are currently at greatest potential risk where acidification, appearing first as an urban-industrial air pollution problem, will probably slowly spread to remote areas.

2.2 Effects on precipitation, lakes and fish.

In Europe itself, strong increases in the acidity of rain since the mid-1950s have been attributed to acids from the combustion of carbon fuels. This has been coupled with substantial increases in the acidity of lakes in Scandinavia and the decline or loss of their fish populations. High acidity is known to be toxic to fish, but the mobilization of aluminium in aci- difying soils is probably involved also, especially during pe- riods of springtime snow melt when soluble aluminium (as Al^{3+}) may infiltrate into lake waters. In Norway some 1750 lakes have lost their fish and 900 others have been severely affected whereas in Sweden, fisheries in 18000 lakes have been seriously affected. Similar incidents have been widely reported from Britain, Ontario and the Adirondack region of the USA. In fact, of a sample of the lakes examined in Europe and North America, half of those with an acidity as great or greater than that indicated by 5.0 on the pH scale of acidity (i.e., an acidity greater than natural rainwater) were fishless compared with one in seven that were less acid than 5.0.

2.3 Effects on forests

Although there were many small indications that European forests may be undergoing damage, in the 1970s, it was not until 1980-83 that dramatic forest changes were clearly recorded. Currently, some 7 million hectares of forest has suffered damage about 5-6 percent of all European forest land with c.0.2 percent completely dead. In FRG an official 1983 forest survey indicatedthat about 34 percent showed clearly visible damage whereas 50 percent was so recorded in 1984. Conifers have been most badly hit, especially the fir (*Abies alba*), followed by spruce (*Picea abies*). A recently reported government survey showed that 30 percent of Swedish forests suffered light to moderate damage (20-60 percent of needles lost on older spruce trees). Although a serious warning, this does not automatically mean that forests are dying over large areas.

2.3.1 Tree die-back by leaf damage and by soil acidification

Although some would argue that the damage cited in Section 2.3 above was caused by drought periods - and dry spells do seem to be connected with tree deaths - there is a broad consensus that forest die-back is currently ascribable to direct leaf or needle damage from deposition. There is however some debate as to which pollutant is the main cause - ozone, sulphuric and nitric acids, ammonia etc., with a good case being made for ozone. The balance of evidence indicates that the interactive effects between all these pollutants are probably so complex that this debate is largely irrelevant. Damage usually takes the form of destruction of the waterproof coating of needles, disintegration of the contents of leaf-cells, severe losses of magnesium from the leaf (an essential component of chlorophyll) and fungal attack. These factors are all consistent with the observed premature yellowing and death of older leaves and accelerated die-back during dry spells.

However, the process of soil acidification and the liberation of soluble soil aluminium may also in time lead to tree death.

The roots of trees take in soil nutrients for their normal growth, tending to leave behind a natural soil acidification. Although most of these basic tree nutrients are returned to the soil in dead leaf- and twig-fall, the remainder, which stay locked up in the tree trunks are responsible for creating a residual acidity in the soil which is compensated for over decades by nutrient-release from the natural weathering of mineral particles in the soil. This means that in their natural undisturbed state, forest soils are in some form of acid balance, determined by these opposing rates of biological nutrient fixation and soil weathering. This balance is significantly upset by the influx of acid deposited from carbon fuel combustion. This externally imposed acidification is most likely to have negative effects on tree growth in the long run. If it continues to an acid increase equivalent to about 4.5 or lower on the pH scale of acidity, soil aluminium comes into solution. This is very toxic to plants, causing direct root damage and preventing root uptake of calcium and magnesium from the soil. Thus, the magnesium lost from the needles by direct leaf damage cannot be replenished from the soil. Likewise, root damage interferes with water uptake in a tree already losing water abnormally through leaf damage. Thus, both soil acidification and direct leaf damage co-act to cause tree die-back.

The question now is whether soil acidification over the recent decades is (a) an accumulative and progressively damaging process leading to regional soil aluminium mobilization in amounts which are (b) sufficient to cause widespread tree toxicity and hence forest damage and destruction.

Recent official reports from FRG indicate that mobile aluminium is present in seepage water of affected forests in concentrations potentially toxic to trees (15-18 parts Al^{3+} per million parts soil water). A recent study showed that soils in the southern part of Sweden have become at least ten times more acid in the last 30 years (topsoils which were regularly between 5.0 - 6.0 on the pH scale of acidity are now between 3.0 - 4.0). This acidification has permeated right down the soil through the tree rooting zone (c. 100 cm). A recent soil map of Sweden shows that large numbers of soils are predominantly more acid than pH4 in the southern half of the country. Soluble Al^{3+} is commonly present around 25 parts per million of soil water. The potentially toxic elements (for humans) cadmium and lead were also brought into solution.

2.3.2 Acidification in tropical forest areas?

It is far less certain what will happen in tropical forest areas exposed to increasing acid deposition as industrialization develops.We do not know if leaves of tropical trees are as sensitive to ozone, NO_x and SO_x acids and ammonia as their temperate counterparts. The lateritic tropical soils contain very low levels of organic matter and very high levels of aluminium in forms unavailable to plants. But evidence exists of purely natural, episodic or permanent acidic conditions in such soils, and tropical vegetation may have evolved a tolerance to soluble aluminium (Al^{3+}) in the same way that vegetation of acid peat-bogs in cool temperate regions is rather tolerant of mobilized aluminium. Conversely the existing acidity of tropical soils may mean that only a relatively small amount of deposited acid may render them useless as growth media? Data are unfortunately not available.

2.3.3 Replacing damaged temperate forests-

If widespread forest death finally occurs in Europe and North America as a result of long-range atmospheric pollutant transport and its replacement is necessary for economic reasons or to prevent a major erosion/siltation crisis from denuded soils, only two strategies are available:

1. If forest die back is caused by direct leaf damage from incoming pollutants, pollution abatement would have to occur prior to replanting the devastated areas.

2. If tree death is additionally caused by acid soils and aluminium toxicity, the soil has been rendered incapable of supporting tree growth.

Under these circumstances pollution abatement must be accompanied by liming (up to 10 tonnes calcium carbonate/hectare, depending on local conditions). Replanting can then be accomplished 1-5 years after liming.

Widespread tree death would probably seriously dislocate the timber market with a wood glut. But this is trivial beside such long-term problems as protracted soil erosion, siltation, lowland flooding, water supply problems to farmland and local climatic change which would make this slow process of tree death an apocalyptic event; a major regional environmental disaster.

If forest areas finally die of acid deposition, they would most likely be replaced by heather moorland or acidic grassland of little agricultural value today. Costs of liming and absolutely minimal improvement even in the most easily treatable areas would exceed US$ 500 per hectare.

2.4 Potential dangers to human health-

Acidified soils will mobilize and liberate into the groundwater such potentially toxic metals as: Cadmium, Mercury, Lead, Nickel, Copper, Chromium, Arsenic, Manganese and Aluminium where these are present naturally or from old industrial sources. They could cause crop damage, hazards to livestock or human health via food and drinking water. Soluble manganese makes water undrinkable. These prospects have not yet been reported in the context of acid deposition. However there are already many cases of premature corrosion of water pipes in rural areas in Sweden and the abundant insurance claims quantify the location and extent of this phenomenon.

3. Remaining Uncertainties

Returning to what is known and what is still uncertain, Section 2 highlighted uncertainties in our knowledge of the effects of deposition on the environment. The following components, although incompletely understood, do not present (compared with Section 2) genuine obstacles to management progress as is sometimes asserted:

1. The nature and extent of chemical transformations of pollutants during atmospheric transport.

2. A detailed understanding of the historical build-up of acidification in rain and snowfall, in freshwater bodies and their sediments.

3. The mechanisms of transfer of pollutant acids from soils to freshwater bodies.

4. The mode of action of fish toxicity.

4. Conclusion

We can conclude that if acidification continues unabated there is a strong risk of losing many more lakes and their fisheries in Europe and North America. Although it is a great economic blow and a loss to our biological and cultural heritage and the quality of human life, - the "Silent Spring" of the world of freshwater - for most people, it does not constitute a national or regional disaster.

However, widespread forest death, may finally occur, either from direct leaf damage, caused by ozone and/or SO_x and NO_x deposition, or worse, by soil acidification and aluminium toxicity, which also means an additional factor of serious soil destruction and erosion. This could constitute a continuing disaster of major proportions. If as the available evidence strongly suggests, soil acidification is a cumulative process, a small reduction of emissions will only slow down the ultimate end. If drastic emissions abatement can be achieved, acidification could possibly be slowed down to the point where normal weathering processes can compensate for the acidification.

Otherwise, we may well be witnessing an immense regional acid-base chemical titration with a potentially disastrous end-point signalled by widespread tree damage and deaths which are a kind of ' environmental litmus paper' indicating the change to irreversible acidification whose costs of treatment would be completely beyond reach.

4.1 The concept of environmentally sensitive areas.

Since the buffering capacity (and hence the ability to withstand acidification) of forest soils varies widely, we would expect to see aluminium first becoming mobilized (and tree die-back from Al^{3+} toxicity appearing first) on the least buffered soils. These are characterized as infertile, well drained (sandy or gravelly) soils with a low exchange-surface capacity per unit volume, with a low organic matter content and a low level of bases. These are classically environmentally "sensitive" areas for acidification. We have no map of them in Europe but a good attempt has been made to characterize them in North America. Since they are vital indicator-areas of more widespread change, they must as a matter of urgency be identified and monitored for symptoms of irreversible acidification.

5. Is the problem outstripping management?

Although governments and industry in North America and several European countries are spending large sums of money on fuel-and gas-cleaning equipment to control the sulphur and nitrogen content of carbon fuels both before and after combustion, when we see damage of the nature outlined in Section 2 above it may well be asked whether current clean-up efforts are adequate? Maybe abatement measures need to be accelerated quite sharply especially if it turns out, as indicated earlier (Section 2.3), that acidification is predominantly a cumulative process.

5.1 Is there International Consensus for Management?

In spite of what has been said so far about the environmental effects of acid deposition, there is nevertheless still a great deal of argument about whether acidification is a serious problem. The arguments versus answers (i.e.the views on the side of emitters v. net receivers) are usually as follows : (arguments v. answers given below:)

1) Damage to trees, soils, water, fish and the microbes in soils and sediments cannot be proven.v. This argument is losing force annually as large-scale death of trees and fish become more obvious,water acidification increases and research demonstrating a causal linkage between acid-deposition and environmental effects becomes stronger, (the answer is believed to be correct).

2) Causes other than industrially emitted SO_x and NO_x must be at work e.g. natural sulphur and nitrogen sources, droughts.v.
As scientific understanding slowly increases, these are now very difficult arguments to maintain (although there is some truth in the drought argument the answer is believed to be substantially correct).

3) Emitters that put out SO_x blame nitrogen emitters for the damage; e.g. tree damage is not caused by sulphuric acid but by ozone, generated in the air by NO_x and exhaust hydrocarbons - So the vehicle industry should bear the main responsibility, not the electric utilities. This argument may be partially valid for trees but cannot explain soil and water acidification nor fish kills satisfactorily (acidification also plays an important role in tree death by co-acting with direct leaf damage (Section 2.3.1 above). Even so, this narrow-minded institutional "territory defending" line of argument cannot be allowed to impede management progress if it is finally decided that the acidification problem needs faster action than it is currently getting).

There are three further arguments commonly used, as follows:

4) Even if responsibility is admitted, the costs needed to abate the pollution are greater than the damage done to the receptors who are challenged by the emitter to prove the opposite before any remedial action can be contemplated.

5) Since it is difficult at present to pinpoint where a specific emission is deposited, the emitter argues that even if abatement were embarked upon, it is impossible to say whether it is being effective.

6) The technology of the problem is improving and if we wait a few years, we shall understand the problem better; and if it still turns out to be caused by SO_x, NO_x and ozone then we shall almost certainly have more cost effective solutions by then.

There are several difficulties with arguments 4-6 above. Regarding No.5, we know that over a large industrialized region such as Europe, deposition is proportional to emission when averaged over a few years. Hence any emission abatement would be expected to produce a corresponding reduction in deposition. This suggests that it is a waste of time to put the blame on <u>one</u> emitter or <u>one</u> type of industry or even <u>one</u> country. Both emission strategies and deposition goals must be worked out collectively. If this could be managed, a lot of temporizing, useless effort, and evasion would be avoided.

Regarding argument 6, given the direction and tempo of research on this topic, it is now unlikely that further work will provide completely new insights, totally revolutionizing abatement management. On the contrary, there is accumulating evidence to show that the real problem with soil and forest damage is that they are proceeding steadily but are still largely cryptic and latent. When they finally do become manifest, pronounced changes are likely to occur over a few years as a result of processes in the soil that have been proceeding since industrialization began and have accelerated substantially since World War II. If this is true, further delay may mean that we shall be forced to deal with the problem when it has assumed crisis proportions. (Sections 2.3; 2.4 above)

One major difficulty with arguments 3 and 5, but particularly with argument 4 is that they beg a fundamental question - What moral, economic or legal right has an emitting agency got to dump pollutants, whatever the level of nuisance or damage they cause, onto a second party be it another agency or an adjacent state? At best it is uncivilized behaviour and at worst, unwarrantable interference in the private affairs of another party or state, tantamount to a hostile act. There is no international law allowing it, or more particularly, no legislation preventing it.

Ultimately, all these arguments boil down to four viewpoints by emitters:

1/ We do not perceive it as any sort of real problem (which is often true).

2/ The national terms of reference which we have to work under as emitters give us no mandate to spend money on the abatement needed (which is often true).

3/ We genuinely cannot afford it (which is sometimes true.

4/ We don't care (which is sometimes true).

PART II MANAGEMENT STRATEGIES

6. Acidification and Development

In Part I above, the problem of environmental acidification has been discussed using as an example the region where it has first manifested itself globally- i.e. in Europe.Although only touched on briefly here, the problem is assuming increasing importance in North America. Attention has also been drawn to the likelihood of its appearing in the Newly Industrializing Countries (NICs). There is little doubt that their dependence on fossil fuels will increase greatly during their period of industrial development. In fact it is no accident that almost all the NICs have large fossil fuel reserves which they will use both as exports to earn hard currency and as fuels to power their own industrial progress. Most of them have such unmanageable development problems of crisis proportions that it would not be an overstatement to say that many would be only too happy if they merely had such manageable problems as environmental acidification to worry about.

7. Basic questions

Having regard to this background, two basic questions must be posed.

1. Despite the existing efforts made by governments and industry in North America and Europe, is enough being done sufficiently rapidly to manage the sources of the acidification problem successfully? This breaks down into four parts:

a) Are we quite satisfied that we have monitored and evaluated the existing rate of onset of European acidification adequately enough to formulate appropriate source-containment strategies ?

b) Are the ranges of institutional, legal and technical management options currently available to us adequate to do the job ?

c) Can we afford them ?

d) Are they currently being actually implemented fast enough?

2. Not unnaturally, we have made mistakes in understanding the acidification problem since it first became manifest. Have we learned all the lessons needed from those mistakes to be able:

a) to make rapid progress in Europe and North America?
b) to pass on to others the types of information needed to describe the problem adequately for management purposes?
c) to say how far the problem in other bio-climatic zones may take on a completely different form e.g., do we know enough about the problem in Newly Industrializing Countries in the tropics and sub-tropics?

A very important consideration here is that it would be hypocritical for industrialized countries to presume to tell developing countries how they should tackle their emerging acidification problems if the industrialized countries do not feel confident that they are well on the way to solving their own. Or at least they should be able to say exactly what ' bottlenecks' are currently holding up progress.

The following Sections deal with these questions. Although European experience is drawn heavily upon to illustrate the range of policy and management issues, especially the important progress being made by governments via the co-ordinating activities of UNECE, the ideas developed could apply to other world regions at future risk from acidification.

Throughout the ensuing text, the discussion of the various policy ideas and issues leads to a series of tentative proposals, put forward to stimulate reaction by the Commission and hopefully serving as a starter for a fully developed considered response to this important problem.

8. Have we monitored and Evaluated Acidification Adequately ?

8.1 EMEP-

At present the only reliable information on collective emissions and deposition across Europe as a whole emerges from the "Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe "EMEP", established in 1977 by UNECE. Table 1 shows an Emission/Deposition Matrix produced by EMEP averaged over four years 1978-1982. Figure 1 shows total Sulphur deposition over Europe for the same period. The joint work of the Oslo and Moscow Centres should be warmly commended and a strong recommendation made that the two Centres be given improved resources to increase their capacity to synthesise the data coming in from the Monitoring Sites in Europe. At present the Centres operate on very slender budgets and both carry a heavy burden of work.

PROPOSAL

The Commission may wish to endorse and commend the work of EMEP and recommend the strengthening of the administrative structures and analytical capacities of its two Centres;

8.2 The idea of acidification units

Many of the initial effects of acidification are cryptic or subtle and have a degree of interconnectedness which is important when looking for symptoms of change. Unless all the components of the whole system of inter-related elements are looked at together, individual, barely detectable trends in each component of the system which may all be seen as pointing in the same direction when taken collectively, will have little significance if examined one by one. Many of these components are the responsibility of different institutions of government e.g. wind patterns, tree growth, soils, water quality, vehicular transport, industrial emissions-control. Information does not flow well across such institutional boundaries.

Thought should be given to the feasibility of governments establishing Acidification Units with authoritative access to all components of the problem so that a systems approach to the management of acidification becomes possible. Some governments are already adopting this approach.

PROPOSAL

It is recommended that those governments that have not already done so, should set up small National Acidification Units or integrated activity Centres with full authoritative access to data on all components of the problem;

8.3 Environmentally sensitive areas-

Acid Rain Units or equivalent national groups should meet and agree on criteria for the production of a national map of areas of increasing sensitivity to soil acidification along the lines indicated in Section 5.1 above. A European Map of sensitive areas and any water bodies contained in them should include basic soil- and water-chemistry characteristics. Symptoms of 'irreversible' soil acidification will be expected to appear in these first and they will form the "litmus paper" for the recognition wide spread European acidification. Such a map is essential if the deposition data emerging from EMEP are to be exploited fully.

PROPOSAL

The Commission may wish to propose the construction of a European map of areas varying in sensitivity to acidification (including soils and water bodies) to be carried out by national groups according to agreed criteria and including basic information on diagnostic features of their soil- and water-chemistry vegetation-type etc.;

8.4 Application to other World Regions-

In Venezuela - Colombia - Ecuador - Brazil; Mexico; Nigeria; Angola and China it is not too early to attempt to see how an "EMEP" type operation might be put together for the region. It probably would not become operational yet but a desk study of such items as monitoring-site selection, sampling and measurement techniques, meteorological data needs, would be extremely instructive.

Likewise, starting up with a genuine systems approach to the problem via Acidification Units would avoid a lot of early mistakes.

Trying to decide the criteria needed in terms of soil features, climate variables and vegetation in order to characterize an environmentally sensitive area would highlight a number of fundamental gaps in our understanding e.g. has buffer capacity and weathering got the same significance for soils in the humid and semi-arid tropics as they have in temperate regions? Are there any data on leaf tolerance to SO_x, NO_x, ozone? What do we know about Al^{3+} toxicity in tropical trees ? What institutions are available to carry out this work if we have no data on the subject? Scientists have been stressing the need to obtain such data for over a decade but have not been able to secure funding for such work. In spite of this difficulty, the 'Scientific Committee on Problems of the Environment (SCOPE) of the 'International Council of Scientific Unions (ICSU), have started a research project in several tropical countries.

PROPOSAL

The Commission may wish to commend the initiative of the SCOPE "Acidification in Tropical Countries" project and urge full financial support for this important work.

Conclusion to Section 8

Although several governments are now actively monitoring soil and water acidification as well as forest damage, this should be expanded to a joint pan-European activity, carried out on conformably inter-comparable lines.

9. Are there affordable institutional, legal and technical arrangements available to manage the problem?

9.1 Ways of Reducing and/or Avoiding Future Emissions

9.1.1 Promoting environmentally favourable energy options-

Closer institutional links should be developed between industry, energy and environment agencies and government departments. By this method it will be possible to promote energy options that reduce or avoid emissions of sulphur and nitrogen. Such an approach helps to integrate environment costs into energy prices. These and other features will be touched upon in Institutional Co-operation (Section 11).

9.1.2. Energy efficiency-

A widely respected and comprehensive global study of energy-demand from MIT concluded: " the effectiveness of energy use on a global scale can be increased by about 1 per cent per year for decades without any social strain. This seemingly small figure leads to a halving of energy use by the year 2050 and a 50 per cent reduction in CO_2 emissions. This result is quite independent of the effect on CO_2 of any shifts to non-fossil sources for primary energy supplies."

This halving of CO_2 production is derived from a halving of the consumption of carbon fuels purely by more efficient energy use. This implies a halving of sulphur and almost a halving of nitrogen outputs without any additional S or N clean-up technology. Economic growth remains unaffected.

The decoupling of energy consumption from GDP is already occuring, stimulated by high oil prices. This approach carries with it so many other environmental benefits that it can be strongly endorsed on many counts.

PROPOSAL

It is proposed that the Commission strongly commend the energy efficiency promoting role of energy accounting and energy audits as well as pricing and subsidy incentives in all sectors of the energy economy as leading to a substantial reduction in the consumption of carbon fuels, and hence SO_x and NO_x output, without affecting economic growth.

9.1.3 Fuel substitution-

Switching to a new fuel affords an opportunity to improve SO_x and NO_x control. The most obviously less polluting fuel in this context is natural gas which is increasingly being used for process heat in industry and district heating systems. It achieves lower emissions of nitrogen and particularly sulphur. Cold-water slurris are capable of being economically de-ashed - a process which removed much of the nitrogen and sulphur compounds prior to combustion.

Although nuclear fuels are ideal substituents for carbon fuels in this respect, there has been so much public anxiety about nuclear power that national nuclear programmes remain stalled in many countries.

PROPOSAL

It is proposed that the Commission commend the use of natural gas and pre-combustion coal cleaning as leading to cleaner carbon fuels. (Any recommendation made concerning nuclear energy may be deferred until this question is directly examined as a separate issue).

9.2 Reduce emissions and improve emission controls-

Reliable "off the shelf" technologies and devices already exist for achieving a high degree of SO_x and NO_x control from nearly any source. Rapid strides contine to be made in the reliability, efficiency and cost reduction of these technologies. The Background Paper gives many detailed examples. This strategy has policy instruments that fall into three broad categories:

9.2.1 Technical standards

The first category depends on the use of technical standards stipulating flue gas concentrations, fuel sulphur contents, or the use of flue gas desulphurization (FGD) at all new coal-fired power stations. West German legislation and certain EEC Directives (recently rejected) have attempted to make detailed stipulations of this type for blanket adoption over several countries. Agreements to use FGD at new coal-fired power stations have already been made, but this is because countries like the UK have no plans to introduce any new installations of this type and, therefore, no action is likely to be required to ensure compliance.

9.2.2 Emission goals

A second approach is to stipulate country emission goals (similar to the EPA "bubble" approach - see Background Document) which express overall national reductions such as 30 per cent or more. It has already been possible to make at least tacit agreement internationally to reduce emissions by 30 per cent, but this is because many countries can achieve the goal without taking any action either because of economic recession or because of the introduction of nuclear power. An advantage of this type of approach is that it leaves the detailed problems of compliance to be determined by individual countries.

It ignores, however, the different patterns of energy use which exist and differences in national opportunities for reducing emissions. It cannot be expected that countries with an entirely different economic structure and with different sources of energy supply will agree to identical emission goals if this means that they will actually need to take any action and incur costs. Other EEC Directives recently attempted to introduce a 40 per cent emission reduction for SO_x but were rejected.

9.2.3 Emission licences (pollution currency)

A third approach bypasses any direct intervention in the large number of specific technical measures required in European countries by introducing a system of decentralized management. This depends on the introduction of emission licences which can be traded amongst polluters.

Countries, or possibly industry groups, would be allocated a specific number of licences which defines the amount of SO_x or NO_x they are allowed to emit over a period. The main feature of the system is that these licences can be bought and sold by polluters and a market will evolve. This virtually guarantees that compliance is achieved in the most efficient possible fashion; it would encourage use of the most technically efficient options in the most economic applications. No intervention in the large number of detailed technical decisions would be required. The system could be extended within individual countries, but legislation used by governments within their own areas of jurisdiction would not be stipulated.

Although the approach has been seriously considered in the USA for several years, no experience has been gained in its actual operation. No recognition is given to the proximity of polluters to environmentally "sensitive" areas; however, modification could be introduced if a licensing system were used to fully implement the co-ordinated abatement policies envisaged in the Beijer Institute modelling programme (see Section 10.1.3). A summary of the three approaches is given in table 2.

Conclusion

The potential for using crude approaches based on technical emission standards or blanket country-emission goals has already been exhausted. If more effective measures are to be implemented, then greater flexibility must be built-in, in order to eliminate obstacles which are created by the system itself and which have little to do with the actual objective of dealing with acidification. In order to make further progress any new measures must take account of:

(i) different national patterns of fuel use and
(ii) proximity of emitters in relation to sensitive areas.

The following phased approach to the introduction of European emission licences is one possible way forward.

As an extension of the Geneva Convention, ECE countries would agrce to the formation of an Air Pollution Licensing Council (APLC). All ECE countries would be represented and it would be agreed that "licensing units" (LU) would be allocated to individual countries and that national compliance would be required. The general objectives of the APLC would be to reduce air pollution in "the most effective possible fashion".

In the initial operating years a sufficient number of licences would be allocated to require only slightly reduced rates of emission. This would allow the system to operate on a "practice" basis and make its setting up more readily acceptable.

The whole package could be phased-in over a period of a few years. It should go ahead more quickly than a new complex package of technical controls or emission goals since these will increasingly become bogged down in the negotiation of special exceptions and exemption clauses needed to take account of diverse local conditions.

PROPOSAL

It is proposed that the Commission recommend a policy study of the feasibility of rapidly implementing emission licences to be carried out by UNECE.

9.2.4 Technology available for control options

Currently available technology for SO_x and NO_x control is listed in Tables 3 and 4 below. Many of these can be applied only in specific energy use sectors; for instance, only in electricity generation or only in transport. Their potential for reducing overall emissions in a particular country will depend on the pattern of energy use which exists. Their economic efficiency in reducing emissions (expressed as $ per tonne of pollutant removed) depends on site-specific conditions but estimates are given. It would be economically inefficient to introduce relatively costly control options unless opportunities for using cheaper alternatives had already been exhausted.

In some countries the cheapest alternative may be FGD on power stations, in others coal desulphurization may be preferable. Little generalization is possible without reference to circumstances in individual local conditions.

Fuel cleaning techniques are relatively simple and well established but their effectiveness depends on the physical characteristics of the specific coals and crude oils which are subject to treatment. The relative economic efficiency of using these options, therefore, varies widely and this is reflected in the broad range of costs shown in Table 3. Considerable local difficulties would arise if these measures were adopted in all European countries. Combustion modification can be used for newly introduced installations and could only have an effect on total emissions over a long period. A wide variety of specific techniques can be used such as fluidized bed combustion and dry limestone injection. It is not possible to define abatement costs precisely since air pollution control would add a relatively insignificant cost and this is, therefore, an attractive option in the limited applications which are relevant.

Information on NO_x control suggests that the use of low NO_x burners at power stations and the introduction of NO_x control on vehicles would be relatively effective in reducing emission and achievable at low cost. Further evaluation is required however (see Table 4).

PROPOSAL

No specific proposal is recommended for consideration. But the Commission may wish to note with satisfaction that SO_x emissions from electricity generation can, in many countries, be reduced by 50 percent at a cost of between 3-6 percent on electricity to the consumer. Additionally, NO_x, carbon monoxide and hydrocarbons from vehicles can be reduced at manageable cost. A 90 percent emissions reduction from gasoline engines and substantial diesel engine emissions-reductions have been achieved in USA at a cost which averages out at less than US dollars 150 a year for the whole emissions-reduction programme.

Thus costs of a drastic source-reduction programme although significant, are very far from crippling for any but the very poorest of industrialized countries.

9.3 Economic Incentives

Mention has already been made of integrating environmental costs into energy prices. Likewise, tax credits or grants can be used to switch users away from coal or oil to gas or to achieve improved building insulation or architectural design for new structures. Generally speaking, it has been found that the costs of reducing sulphur and nitrogen keep pace with the environmental benefits of doing so.

9.4 Application to other World Regions-

Many large installations potentially emitting sulphur and nitrogen e.g. electric power stations, smelters etc., are built using development aid assistance. Although the World Bank reviews all its projects for their environmental appropriateness, this is not always the case with national Development Aid Agencies.

PROPOSAL

It is proposed that any new energy producing or consuming installations should be reviewed for their efficiency in reducing nitrogen and sulphur emissions. National Development Aid Agencies should be urged to take appropriate measures to ensure this.

Conclusion to Section 9

The institutional, legal and technical arrangements available to manage the problem are adequate given the political will to do so. They are also affordable.

10. Are the current arrangements for source abatement being implemented fast enough?

Judging by the continuing acidification of lakes, soils and forests in Europe, the answer is "no". More vigorous governmental action needs to be channeled into support for the excellent co-ordinating work already being done by UNECE. The proposals made in Sections 8 and 9 above go some way to suggesting items for accelerated action. There are however other useful additional items which the Commission may wish to consider, as follows below:

10.1 Improving the information base on acidification

10.1.1 Emissions Inventory

Reporting procedures for the return of consumption, import and export statistics, nitrogen and sulphur contents of carbon fuels to the UNECE should be reviewed in the light of the special requirements of the EMEP.

PROPOSAL

It is proposed that consideration be given to reviewing the reporting procedures for sulphur and nitrogen contents, import, export and consumption data on carbon fuels by governments to UNECE in the light of the special requirements of EMEP.

10.1.2 Applications to other World Regions

Where such inventories do not exist, desk-study "attempts" to set them up in NICs would help to focus on data needs and how to collect them.

10.1.3 Co-ordinated policy development

Co-ordinated policy development is a slow process. It will take several years to develop and to appreciate the full implications of control policies. Thus the sooner policy development starts, the easier it will be to formulate agreed abatement strategies. Two initiatives briefly referred to here are of special interest. The international Institute of Applied Systems Analysis (Vienna) is developing an "accounting" model. This can convert emissions and deposition data obtained via EMEP into European soil pH maps. This then will enable the effects of any abatement policy proposals made under the UNECE Convention to be predicted. For example the effects of implementing the results of the abatement actions carried out under the "Thirty Percent Club" can be predicted.

The other initiative is being undertaken by the International Institute for Energy and Human Ecology - Beijer Institute - Stockholm and its Centre for Resource Assessment and Management in York - U.K. This is a modelling programme involving an environmental and economic study designed to identify the abatement policies which would be required at national level in order to reduce depositions in environmentally sensitive areas at minimum total cost to the European Region. This will also use deposition data obtained from EMEP. Several alternative solutions will be available, depending on the constraints present in political implementation by various governments. The emissions optimization strategy will serve as a useful guide to longer-term pan - European emission policy development by UNECE.

PROPOSAL

It is proposed that programmes such as those being undertaken by the International Institutes at Vienna, Stockholm and York on co-ordinated policy development be endorsed and encouraged to grow in tandem with technical and scientific research on acidification (not following on after it). This recognizes the fact that acceptable co-ordinated policy development takes several years to become mature.

10.1.4 Co-ordinated policy development in other world regions

This type of work is probably premature for other World regions, but nevertheless the feasibility of starting it could be assessed.

11. Institutional issues.

Section 5.1 drew attention to problems that arise when individual institutions have responsibility for energy production in different sectors of the energy economy. It is often the case that a national electrical utility will be given terms of reference requiring it to produce electricity at the cheapest price possible, with due regard to human safety, but not environmental safety.

Or a coal company can ignore the environmental implications of coal use, without which gas is an expensive (though environmentally cleaner) alternative. In fact there are numerous examples where energy production, particularly of carbon fuels have no sound relation to the environmental impacts of energy use. This indicates that governments responsible for drawing up the terms of reference for national energy agencies and for the legislation governing the modus operandi of the private sector energy agencies must make allowance for the environmental dimensions of energy consumption particularly with regard to pricing policy. This relates to considerations in section 9.1.1 above.

PROPOSAL

It is proposed that the Commission recommends that national governments should re-examine the terms of reference laid down for national energy agencies and the legislation controlling the operation of private sector agencies, with a view to ensuring that due regard is paid to the costs of environmental impacts in setting production procedures and pricing policies for energy.

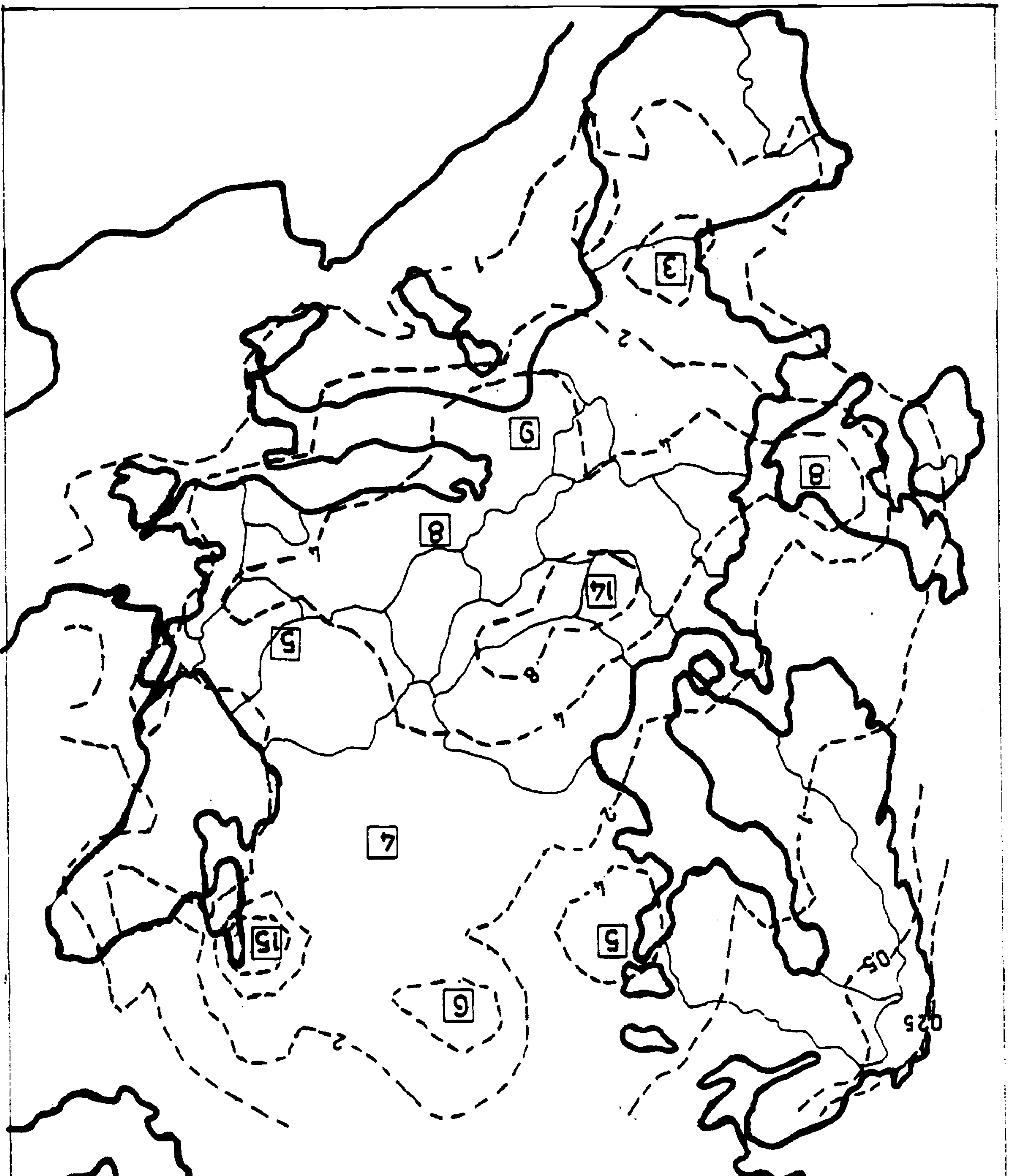

Fig 1. Isolines of Average Annual Total Deposition of Sulphur (expressed as grams Sulphur/square metre of ground/year and based on the period October 1978 - September 1982. Maxima are shown as boxed numbers, in the same units).
Redrawn from EMEP/MSC-W Report 1/85.

MEAN ANNUAL DEPOSITION FOR THE PERIOD 78 10 1 12 TO 82 10 1 6

TOTAL (DRY+WET) DEPOSITION OF SULPHUR

HORISONTAL - EMITTERS

VERTICAL - RECEIVERS

UNIT - 1000.TONNES SULPHUR PER YEAR

Emitter countries ——>

Receiver countries ——>

	AL	A	B	BG	CS	DK	SF	F	DDR	D	GR	H	IS	IRL	I	L	NL	N	PL	P	R	E	S	CH	TR	SU	UK	YU	RE	IND	SUM
AL	12	0	0	3	2	0	0	3	2	1	3	3	0	0	12	0	0	0	1	0	1	1	0	0	0	0	1	19	1	14	85
A	0	62	3	0	46	0	0	26	31	40	0	16	0	0	72	1	2	0	17	0	1	4	0	4	0	2	11	42	0	36	422
B	0	0	84	0	2	0	0	34	3	29	0	0	0	0	1	1	6	0	1	0	0	1	0	0	0	0	21	0	0	12	190
BG	2	1	0	159	11	0	0	3	9	6	9	17	0	0	12	0	0	0	10	0	23	2	0	0	5	13	2	57	1	35	413
CS	0	15	5	1	440	1	0	24	131	59	0	61	0	0	24	1	4	0	80	0	5	2	0	2	0	7	14	43	0	37	969
DK	0	0	2	0	4	47	0	5	14	14	0	1	0	0	1	0	2	0	6	0	0	0	2	0	0	1	15	1	0	14	132
SF	0	0	3	1	10	5	92	7	25	20	0	4	0	0	2	0	3	2	22	3	1	0	17	0	0	53	20	4	0	66	363
F	0	2	41	0	15	1	0	760	33	124	0	2	0	3	40	6	17	0	9	3	0	94	1	9	0	1	122	6	2	205	1505
DDR	0	2	10	0	64	4	0	25	586	103	0	5	0	0	5	1	0	0	29	0	1	1	1	1	0	3	28	7	0	30	910
D	0	9	45	0	60	6	0	136	149	660	0	7	0	1	31	6	27	0	24	0	1	9	1	0	0	3	80	15	0	96	1300
GR	4	1	0	39	5	0	0	4	5	5	111	7	0	0	20	0	0	0	4	0	5	3	0	0	5	5	2	37	2	36	308
H	0	11	1	3	56	0	0	9	25	17	0	227	0	0	36	0	1	0	29	0	11	1	0	0	0	5	5	93	0	24	560
IS	0	0	0	0	0	0	0	0	0	1.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	20	26
IRL	0	0	0	0	0	0	0	2	1	2	0	0	0	22	0	0	0	0	0	0	0	1	0	0	0	0	15	0	0	32	80
I	0	0	3	2	17	0	0	68	17	29	1	14	0	0	940	1	2	0	11	0	2	22	0	0	0	2	13	73	6	103	1355
L	0	0	1	0	0	0	0	4	0	2	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	1	0	0	1	14
NL	0	0	21	0	3	0	0	19	7	51	0	0	0	0	1	0	53	0	1	0	0	1	0	0	0	0	33	1	0	14	210
N	0	0	5	0	9	9	2	15	26	25	0	2	0	1	2	0	5	24	14	0	0	2	11	0	0	9	53	3	0	92	314
PL	0	9	11	3	168	10	1	36	270	106	1	40	0	1	26	2	10	0	776	0	0	3	5	1	1	36	41	45	0	90	1712
P	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	25	0	16	0	0	0	0	1	0	0	30	80
R	1	5	2	35	49	1	0	11	35	23	5	91	0	0	34	1	2	0	54	0	192	2	1	1	4	53	8	143	1	70	627
E	0	0	3	0	2	0	0	44	6	22	0	0	0	0	4	1	3	0	1	11	0	429	0	1	0	0	17	1	3	113	666
S	0	1	7	1	22	23	12	19	53	45	0	6	0	1	7	1	7	10	41	0	2	2	100	0	0	27	51	0	0	130	507
CH	0	1	2	0	4	0	0	29	6	19	0	1	0	0	45	0	1	0	2	0	3	4	0	16	0	0	7	3	0	21	165
TR	1	1	0	37	8	0	0	5	9	6	25	10	0	0	16	0	1	0	9	0	0	4	0	0	209	23	2	30	2	93	505
SU	4	17	23	80	221	30	60	82	342	233	27	135	0	3	100	5	29	6	538	0	139	11	45	4	53	4273	126	232	3	1090	7972
UK	0	0	9	0	5	1	0	35	12	26	0	1	0	0	1	1	7	0	4	0	0	5	0	0	0	1	790	1	0	87	996
YU	4	19	3	39	52	1	0	32	35	30	6	86	0	0	193	1	3	0	30	0	17	10	0	2	1	10	13	678	3	106	1377
	AL	A	B	BG	CS	DK	SF	F	DDR	D	GR	H	IS	IRL	I	L	NL	N	PL	P	R	E	S	CH	TR	SU	UK	YU	RE	IND	SUM

Table 1: Calculated European sulphur budget for a 4-year period starting 1 October 1978. Unit: 10^3 tonnes of sulphur per annum. Assumed emissions are given in Table 2. Depositions from emitter countries are given in vertical columns, depositions to receiver countries in horizontal rows. IND signifies indeterminate wet depositions. Total estimated deposition is given as SUM in the right-hand column.

TABLE 2. Policy Instruments

Instruments	Subject of Control	Special requirements	Advantages/Disadvantages
Technical emission standards	Individual combustion installations or fuel types	All standards would require a complex system of dispension to deal with special local circumstances. Additional controls may be required to prevent more intensive use of emission sources not covered by emission standards	*Use of FGD on new power station has already been agreed internationally. *Lack of flexibility in any effective set of standards. *Economic inefficiency. *No recognition of targeting in relation to sensitive areas.
Emission goals	Individual nations, or possibly industry groups	Flexibility may be required in agreed goals because of uncertain future economic growth and energy use. Provision will be required for differential country emission goals because of differences in patterns of energy use.	*30 per cent reduction already widely agreed. *Lack of flexibility prohibits more stringent common goals. *No recognition of targeting in relation to sensitive areas

/continued

TABLE 2. **Policy Instruments** (continued)

Instruments	Subject of Control	Special requirements	Advantages/Disadvantages
Tradeable licences	Individual nations	Flexibility is built in but new institutions are required	*Inertia in setting up new institutions *Potential occurence of speculative markets for licences *No recognition of targeting in relation to sensitive areas

TABLE 3. Control options for SO_x (adapted from UNECE (1982))

Technique	Removal efficiency (%)	Applicability	Economic efficiency ($ per tonne SO_x removed)	Principal determinants of cost variations
Physical coal cleaning	10 - 40	Electricity generation, district heating, industry	0 - 900	(i) Coal quality (ii) Per cent reject (iii) Level of cleaning (iv) Type of coal processing already in existence for grading or other market purposes
Oil desulphurisation	80 - 90	as above	250 - 1,000	(i) Quality of crude (ii) Specific technique used
Combustion modification	50 - 90	New boilers	(undefined)	(i) Size of boiler (ii) Specific combustion technique used
FGD	85 - 95	Electricity generation, district heating, industry	225 - 600	(i) Load factor of power plan (ii) Remaining years of servic for retrofitted plant (iii) Specific FGD technique used (iv) Size of combustion plant

TABLE 4. **Control options for NO_x (adapted from HMSO (198[illegible]))**

Technique	Removal efficiency (%)	Applicability	Economic efficiency ($ per tonne NO_x removed)
Low NO_x burners	30	Electricity generation district heating, industry	(not available)
FGD	80	as above	(not available)
Exhaust gas recirculation	-	Vehicles	(not available)
Lean burn engines	-	as above	(not available)
Catalysts	-	as above	(not available)

TABLE 5. Control options for NO_x (adapted from HMSO (1984))

Technique	Removal efficiency (%)	Applicability	Economic efficiency ($ per tonne NO_x removed)
Low NO_x burners	30	Electricity generation district heating, industry	(not available)
FGD	<80	as above	(not available)
Exhaust gas recirculation	-	Vehicles	(not available)
Lean burn engines	-	as above	(not available)
Catalysts	-	as above	(not available)

W/100g/mr

WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT

THIRD MEETING
Oslo, 21-28 June 1985

WCED/85/16 Add.1

Item 6.1 of the Provisional Agenda

BACKGROUND PAPER ON ACID RAIN

ACID RAIN AND AIR POLLUTION:
A PROBLEM OF INDUSTRIALISATION

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PREPARED FOR THE WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT

JUNE 1985

PREFACE

This background paper reviews the acid rain issue from the international perspective. It explores the current state of knowledge of the mechanisms and effects of acid deposition and related air pollution, and discusses the technologies and methods available for reducing emissions of the principal pollutants concerned, as well as their costs. It seeks to define some of the main economic issues involved in acid rain control, and finally discusses some conclusions of particular relevance to the work of the World Commission on Environment and Development.

While the paper is presented by the author in his personal capacity, his involvement in the substantial past and present work in areas related to this topic in the Organization for Economic Co-operation and Development has provided a valuable source of information and insight. In addition to OECD published work, the paper draws upon a number of major reports issued by public and private bodies, nationally and internationally, over the past few years, and attempts to provide as up to date as possible a picture of the science, economics and politics of acid rain.

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A NOTE ABOUT THE AUTHOR

Dr. Ian Torrens holds a Ph.D. in Physics from the Cavendish Laboratory, University of Cambridge in the United Kingdom, and has spent the earlier part of his career in research in the field of nuclear reactors. Between 1974 and 1980 he was involved in the work of the International Energy Agency of the OECD, notably as Head of the IEA's Oil Industry Division. Since 1980 he has headed the Resources and Energy Division of the OECD Environment Directorate, which is responsible for work in the fields of energy and environment, air pollution, water management and hazardous wastes. He is the author of numerous articles and papers in the environmental field, particularly with regard to coal and the environment, and to air pollution including acid rain.

ACID RAIN AND AIR POLLUTION
A PROBLEM OF INDUSTRIALISATION

(*)
IAN M. TORRENS

I. INTRODUCTION

"Acidity is caused almost entirely by sulphuric acid, which may come from coal or the oxidation of sulphur compounds from decomposition, but it may also be caused in manufacturing towns by other acids, and in country places to a small extent by nitric acid and by acids from combustion of wood, peat, turf, etc."

This quotation, taken from a book by R.A.Smith, General Inspector of Alkali Works for the British Government, published in 1872 (1), shows that acidification of the environment is not a new concern. Smith observed that where rain contained more than 40 parts per million of sulphuric acid it prevented the growth of vegetation, damaged buildings, rusted metals, rotted blinds and faded colours in prints and dyed goods. Though he was concerned with local pollution and unaware of the long-range effects of acidic compounds transported by the atmosphere, his study is surprisingly topical given present day concerns in many countries about the effects of acid rain and air pollution generally.

Today, the sources of the air pollution, and the proportions of different pollutants emitted, are somewhat different; taller chimneys have ensured that these pollutants travel greater distances before returning to earth; different living patterns and environmental protection measures taken to combat pollution have reduced some of the damage observed by Smith. But new concerns have arisen; new types of damage, especially through long-range

(*) The views expressed in this paper are those of the author in his personal capacity and do not necessarily represent those of the OECD or of its Member countries.

transport of pollutants, have come to the fore; the ubiquitous motor vehicle has emerged as a major source of pollution; and the problem has moved into the international arena.

II. A PROBLEM FOR FISH, FORESTS - AND HEADS OF GOVERNMENT!

The term "acid rain" (or more correctly "acid deposition" which includes both wet and dry forms) held little meaning except for scientists specialising in environmental matters and some frustrated fishermen in Scandinavian countries, until the past decade. Its political prominence rose over a relatively few years to the point where it is now an issue for the attention of the highest levels of government in many countries, particularly in Europe and North America.

Why this sudden fame - or infamy? The explanation is quite complex but has to do principally with the fact that acid rain has important transfrontier effects, and therefore international political implications; and with the fairly recent discovery during the first half of the present decade of severe and accelerating damage to the forests of central Europe (of which acid rain is probably one of a number of causes, as indicated later in this paper).

Acid rain and related air pollution problems now obtain regular news media coverage; they provide the central themes for many scientific and economic conferences and meetings and are an important component of innumerable others. They are also on the political agenda whenever environment ministers come together in various international fora. Recently they received the attention of the heads of government of the European Community and of the seven major industrialised countries' economic summit meeting held in Bonn in May 1985.

There are indications that acid rain will continue to occupy a prominent position on the political agenda of the regions principally affected, and that it will come to greater prominence in some countries and regions where awareness of the air pollution problematique is still at an earlier stage in its evolution - among these the newly industrialising regions of the world.

What precisely are the problems - scientific and economic - associated with acid rain? Why has such an intense political debate developed around the acid rain issue? And what can be done to contribute to a solution to the air pollution problems involved? These are questions which this paper will attempt to answer in the Sections to follow. The responses may however be foreshadowed by a very brief definition of the views of the main protagonists in the ongoing political debate, which can provide a useful backdrop to the more detailed explanation of the state of knowledge and of the issues involved.

The Key Question

The main question which policymakers must ask is the following: In the light of the costs of reducing air pollution and the benefits this might yield, should action be taken; and if so what, and to what extent? A rather polarised version of the two main sets of views which have been expressed might read approximately as follows:

In favour of action

- While we do not yet know all the answers, serious environmental and economic damage is clearly being incurred;
- This damage may well be accumulative, so that past air pollution may be reflected in future damage;
- Some of the damage may turn out to be virtually irreversible;
- It will take years, in come cases even decades, to answer the main questions fully;
- We have the technological capability to achieve large reductions in emissions of the air pollutants involved at a cost which is in most cases economically acceptable;
- Even if we act now it will take up to a decade before a control programme yields its full results in reduced emissions, so there is no time to waste.

In favour of delay

- Scientific research is making rapid progress in providing some answers to the important questions;
- Major research programmes in a number of countries can be expected to achieve further progress in knowledge over

the next few years;

- The past decade has seen significant reductions in the emissions of major air pollutants in many industrialised countries;
- The costs of reducing air pollutant emissions further are relatively large, and there is no proof that the benefits of a control programme will be as large;
- New technologies for control of emissions which are considerably less costly than those presently available may be developed over the next decade or two;
- Consequently it would be unwise to take expensive and precipitous action which may be shown by further research to have been unnecessary or inappropriate.

Further complexities are added by the transfrontier aspects of acid rain. Air pollution originating in one country can and often does cause environmental damage in another, and while there may be moral and political pressure on the country of origin of the pollutants to take action to reduce this transfrontier pollution, there is as yet no international legal obstacle to such practices.

How did such controversy come about? The next Section reviews the historical evolution of the acid rain issue from the 1950's to the present day. Figure 1 contains a schematic view of the problems and the possible solutions, with particular emphasis on the economic implications.

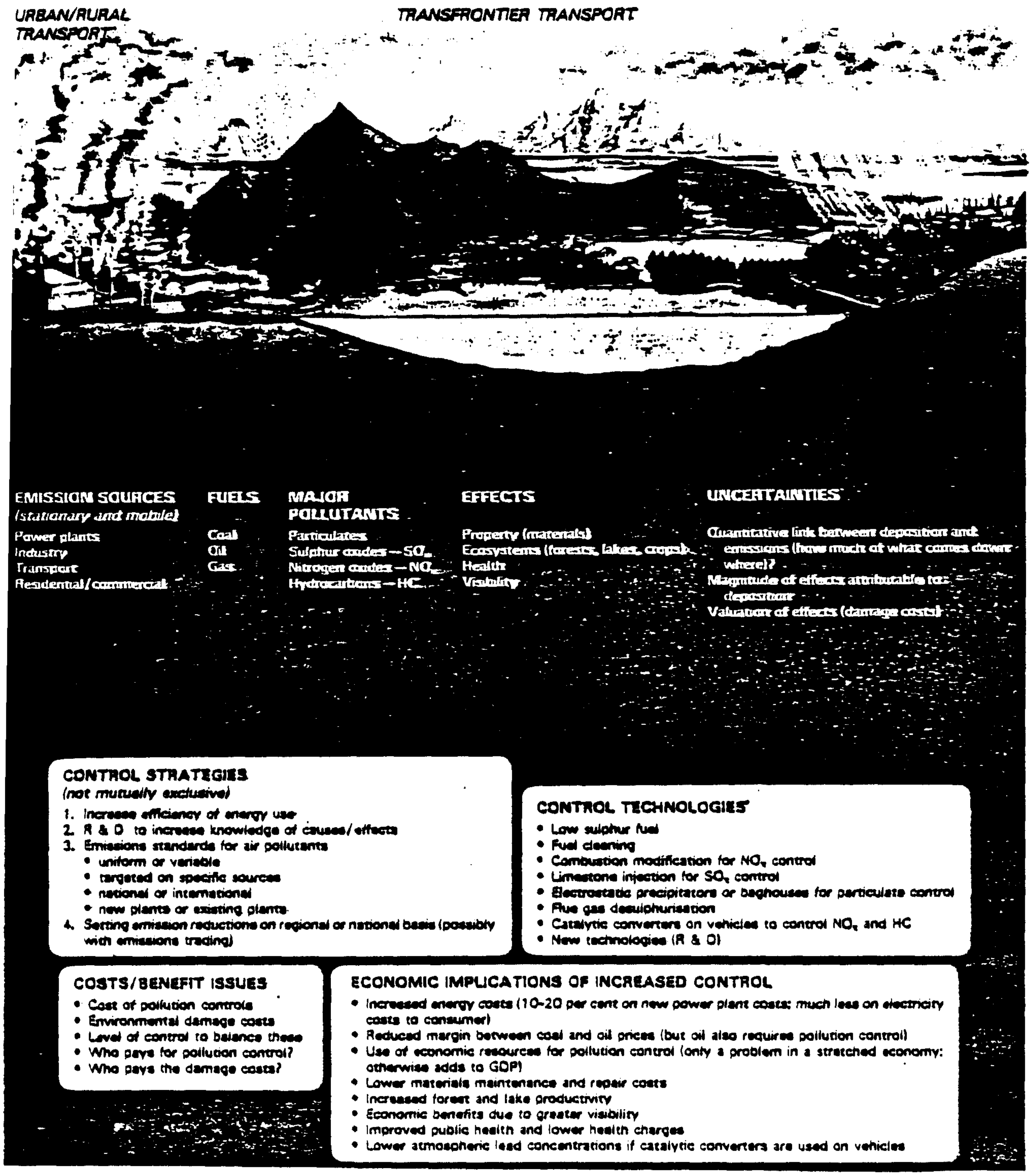
III. <u>THE ACID RAIN ISSUE YESTERDAY AND TODAY</u>

During the 1950's and 1960's a network of stations for measuring the chemical composition of precipitation in Europe observed that this precipitation at many of these stations wasbecoming more acidic. This observation was associated with the acidification of the water in rivers and lakes in Scandinavia, where in many places the fish population had disappeared.

In 1972 the Organisation for Economic Cooperation and Development (OECD) launched a "Cooperative Technical Programme to Measure the Long-Range Transport of Air Pollutants (LRTAP)" with the objective of determining "the relative importance of local and

FIGURE 1

SCHEMATIC VIEW OF THE ACID RAIN PROBLEM



distant sources of sulphur compounds in terms of their contribution to the air pollution over a region, special attention being paid to the question of acidity in atmospheric precipitation". The study was completed in 1977 and the findings have been published (2). The programme confirmed that sulphur compounds do travel long distances in the atmosphere, and showed that the air quality in any one European country is measurably affected by emissions from other European countries.

It was apparent from this OECD study that the long-range transport of air pollutants in Europe concerned the whole region and not just the OECD Member countries. This led the United Nations Economic Commission for Europe (UNECE) to establish in 1977 the "Cooperative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe (EMEP), and to develop a Convention on Long-Range Transboundary Air Pollution. This Convention was signed in 1979 by 34 countries and entered into force in March 1983. Parties to the Convention undertook to "limit and, as far as possible, gradually reduce and prevent air pollution including long-range transboundary air pollution".

In North America, growing awareness of the important impacts of acid precipitation began in the mid-1970's. The Canadian Network for Sampling Precipitation began in 1976; the National Atmospheric Deposition Program was started in the USA in 1978. The data from these programmes showed that about two-thirds of the total land area of North America receives acid precipitation. As a result of these studies the governments of Canada and the United States in 1980 signed a Memorandum of Intent to develop a bilateral agreement on transboundary air pollution including "the already serious problem of acid rain".

The past few years have seen initiatives by the governments of the Nordic countries, Canada and the Federal Republic of Germany to bring Ministers responsible for the environment together at major Conferences with a view to giving a new political impetus to the control of acidifying emissions. In the first instance, the 1982 Stockholm Conference on Acidification of the Environment provided a "state-of-the-art" experts' report on what was then known about acidification, and developed a set of policy conclusions for action to reduce it.

Following this, the Nordic countries developed a proposal for the first meeting of the UNECE Executive Body for the Convention on Long-Range Transboundary Air Pollution held in June 1983. Their proposal called for parties to the Convention to agree to reduce national emissions of sulphur dioxide by at least 30 per cent by 1993, using 1980 levels as a reference. This proposal was supported by a number of other UNECE countries, and the group became informally known as the "Thirty Percent Club".

In March 1984, the Canadian government invited all UNECE countries who accepted the Nordic proposal to a Ministerial level Conference in Ottawa, in order to provide added impetus. Again, several additional countries joined the "Thirty Percent Club" on that occasion.

The government of the Federal Republic of Germany then invited Ministers of all countries who were parties to the Convention to a Multilateral Conference on the Environment in June 1984. This Conference recommended to the Executive Body, *inter alia*, that an agreement on a specific reduction in sulphur emissions should be negotiated in the UNECE under the auspices of the Convention.

The Executive Body, at its second meeting in September 1984, set up a Working Group charged with negotiating a Protocol on specific sulphur emission reductions. The Working Group completed its task in the form of a draft Protocol which will be submitted to the third meeting of the Executive Body, to be held in Helsinki in July 1985. By May 1985, a total of 21 countries had "joined the Thirty Percent Club" by indicating their willingness to achieve the stated reduction in sulphur emissions, or in their transboundary fluxes. This provides an indication of the number of countries expected to sign the Protocol in July 1985.

IV. ACID RAIN AND AIR POLLUTION: CLEARING UP SOME CONFUSION

The term "acid rain" has become shorthand for a widening range of perceived environmental problems stemming from air pollution, and in common with many such over-simplifications, its use (or misuse) often leads to inaccuracies and confusion. This can be quite counter-productive in a field where the complexities render the most knowledgeable attempt to describe the causes and effects fraught with uncertainty.

It would be advisable, therefore, to set the bounds as clearly as possible from the outset. In fact, acid rain is only one aspect of a wider set of environmental problems which owe their origin, in whole or in part, to the range of air pollutants emitted by various industrial or other economic activities. The more correct form for acid rain is acid deposition, which includes both wet and dry forms. But in order to understand better the effects of acid deposition, and to take measures to remedy them, we need to widen our horizons still further to consider air pollution more generally, since some of the effects seem to be related to the quality of the airshed rather than to particular substances which are deposited in a specific place.

The major air pollutants implicated in the types of phenomenon attributed in whole or in part to acid deposition are sulphur oxides (SOX), mainly sulphur dioxide (SO2); nitrogen oxides (NOX); hydrocarbons (HC), also sometimes described by a number of other terms such as volatile organic compounds (VOC); and particulate matter (PM). These pollutants are emitted in various proportions from both stationary sources and vehicles. The stationary sources responsible are essentially power plants, industry, and residential or commercial buildings. Most of the emissions arise from the combustion of fossil fuels - coal, oil and gas - though in some countries there is a substantial contribution from ore smelting.

The pollutants emitted are subject to interaction with each other and with other atmospheric substances. For example, atmospheric ozone - one of a range of photochemical oxidants - is formed by interaction of NOX and HC in the presence of sunlight, and has been implicated in photochemical smog as well as in damage to plants and trees. Atmospheric pollutants can travel considerable distances (up to and sometimes more than a thousand kilometres) depending on the conditions of their emission and on climatic factors. Thus acid deposition in any one location may be the result of emissions over a very large area, especially if averaged over a lengthy time period. Figure 2 shows the annual mean sulphur deposition (both wet and dry) over continental Europe. Annex 1 contains some figures from a computer model which illustrate on an individual emitting and receiving country basis

FIGURE 2

SULPHUR DEPOSITION IN EUROPE

BEING REDRAWN (G. GOODMAN)

the transfrontier transport of sulphur compounds.

More recently another pollutant, ammonium (NH4), has been implicated by some scientists in the types of damage attributed to acid deposition, particularly to vegetation. An important source of this is excessive use of fertilisers in agriculture.

Because of the range of sources and the complexities of the atmospheric processes and the effects following deposition, any strategies to address the problems of air pollution need to be developed with the objective of covering all sources of these pollutants - both stationary and mobile.

V. A PROBLEM OF THE INDUSTRIAL ERA

There was in recent years some controversy about the real causes of acidification of the environment, and more specifically the respective role of natural and man-made emissions of sulphur and nitrogen compounds in the effects attributed to acid deposition. A careful examination of the evidence has largely removed any doubt that the activities of industrialised homo sapiens bear the prime responsibility in all but very isolated cases in both geographic terms and over time.

Measurements of acidity in preserved snow have shown that levels of acid deposition were much lower before the industrial revolution some two centuries ago. In fact, the precipitation in previous ages was generally lower in acidity than the present background average in remote parts of the world, only reaching this average in years when it was affected by volcanic eruptions. Further evidence comes from examining the sediment of lake beds, and indicates that the acidity of Swedish lakes, which had been stable at close to neutral since the last ice age, increased a hundredfold during the last several decades.

Globally, about 60 percent of total sulphur emissions are man-made. However, the bulk of man-made emissions occurs in industrialised regions covering less than 5 percent of the earth's surface: Europe, Eastern North America, China and Japan - and they account for more than 90 percent of total sulphur emissions in these areas.

Consequently, any problems of the natural or man-made environment attributable to acidification are likely to respond to efforts to reduce man-made emissions of the responsible substances, and there is little danger, except in isolated circumstances, that nature will take over the polluting role.

VI. AIR POLLUTION TRENDS IN INDUSTRIALISED COUNTRIES

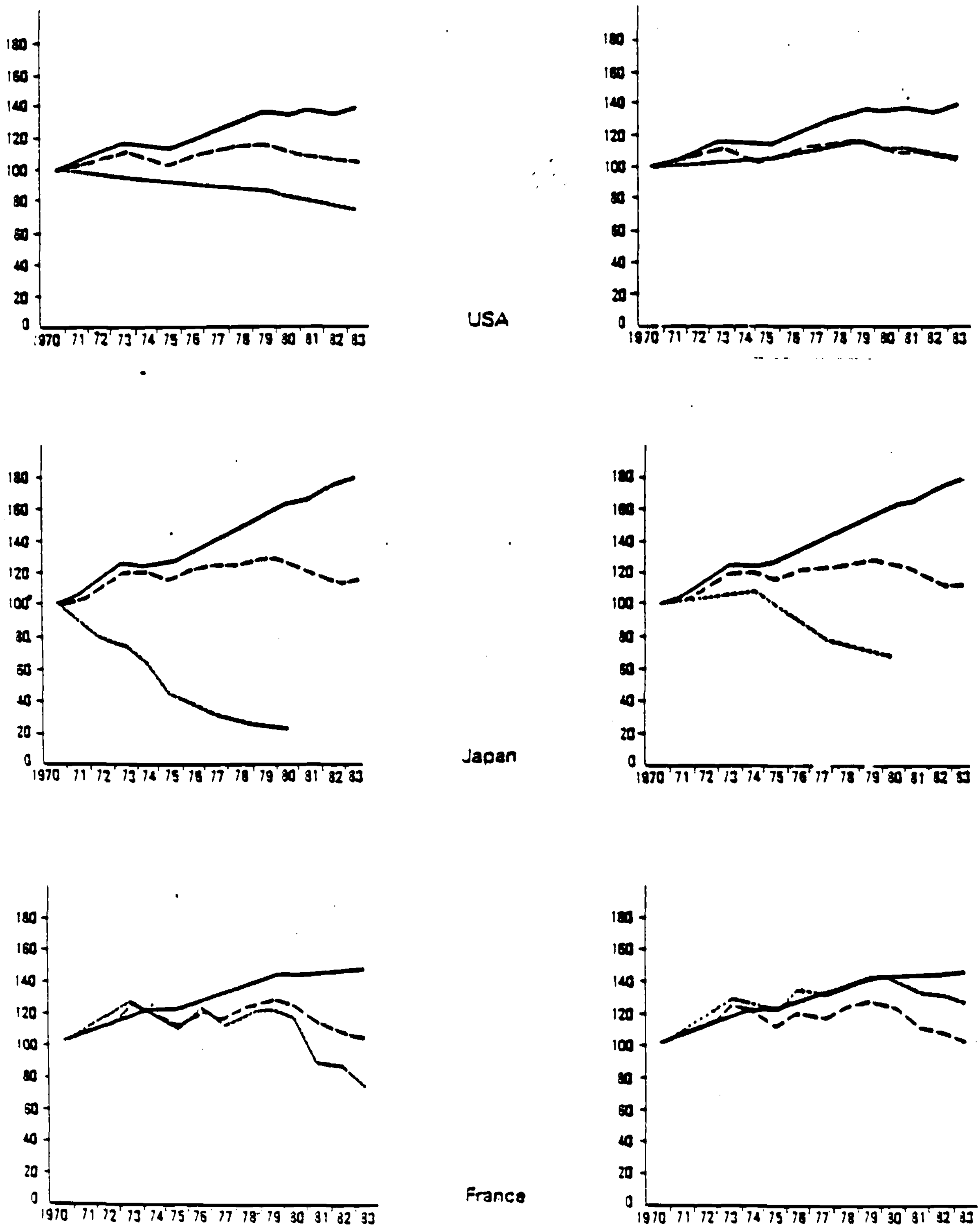
Between World War II and the late 1960's, the process of industrialisation with little attention given to protection of the environment caused a fairly clear increasing trend in the gaseous air pollutants. Increasing consciousness of health and environmental risks led to control measures being taken in a number of countries during the 1970's and up to the present, which were reflected in a slowing down of the increase in emissions, and in some cases in a actual decrease. These measures to some extent decoupled pollutant emission trends from economic growth trends - a decoupling which is necessary if conflicts between growth and a healthy environment are to be avoided or at least minimised.

Some examples may be cited. The OECD has recently issued a new report on the state of the environment together with a Compendium of Environmental Information for OECD countries on a comparable basis (3). This Compendium contains in particular some detailed information on trends in emissions of sulphur and nitrogen oxides in OECD countries since 1970. Figure 3, extracted from the Compendium, illustrates the trends in sulphur and nitrogen oxide emissions in the USA, Japan and France, comparing them with trends in GDP and in total fossil fuel requirements. All major industrialised countries have experienced a significant decoupling of total <u>energy</u> requirements (as distinct from simply fossil fuel requirements) from economic growth since the large increase in oil prices occurred in 1973, as illustrated by Figure 4.

FIGURE 3

TRENDS IN SULPHUR AND NITROGEN EMISSIONS

SULPHUR OXIDES NITROGEN OXIDES



Legend:

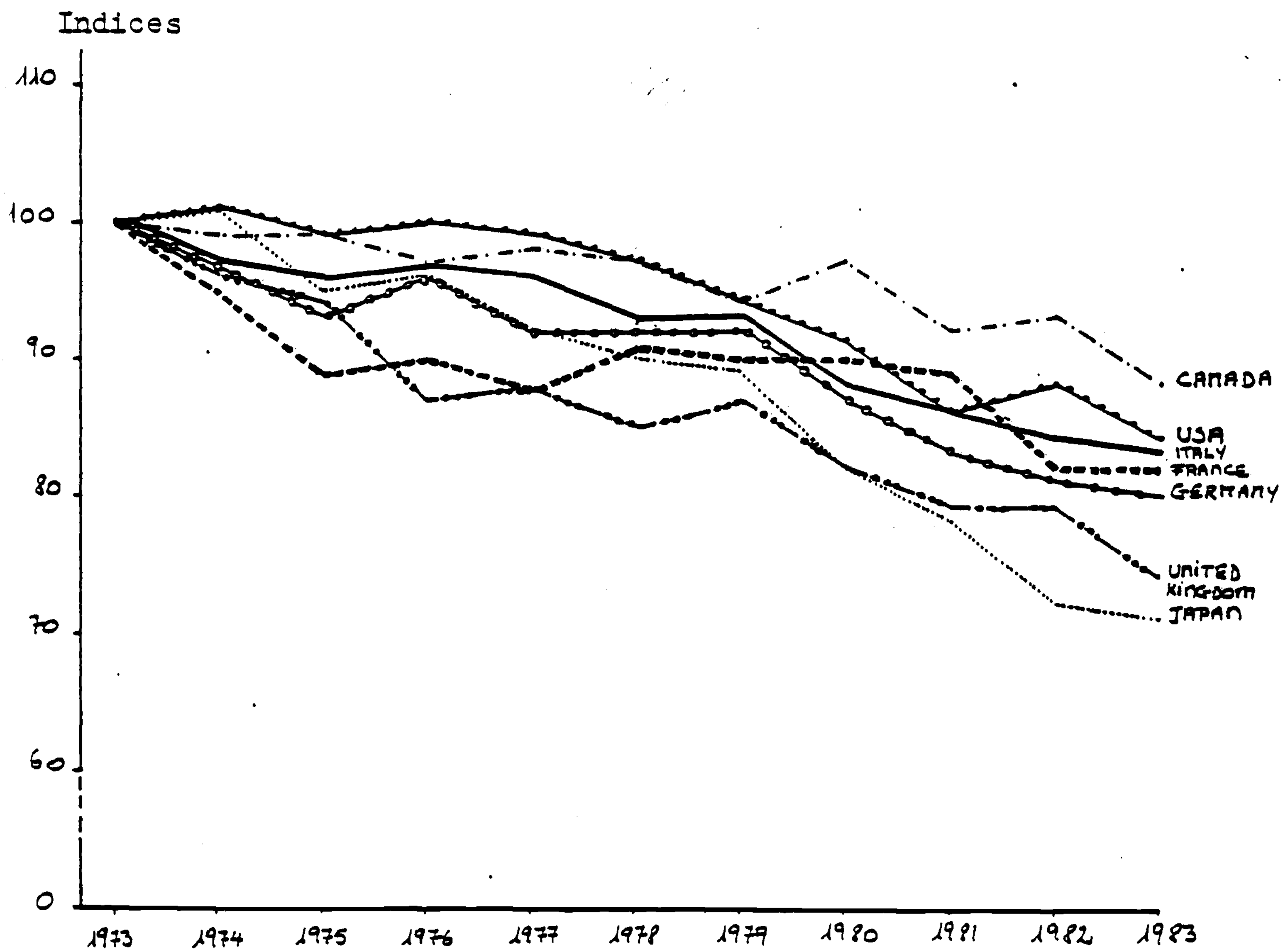
- Gross Domestic Product
- Total Fossil Fuel Requirements
- Total Emissions

Indices, base 100 in 1970

Reference: OECD Compendium 1985

FIGURE 4

TOTAL PRIMARY ENERGY PER UNIT OF GDP IN MAJOR INDUSTRIALISED COUNTRIES



Note : Indices (base 100 in 1973) are calculated from values of ratio

$$\frac{\text{Total Primary Energy Requirements}}{\text{Gross Domestic Product}}$$

Source : OECD Economic and Energy Statistics

The curves of Figure 3 show that some degree of further decoupling of emissions of sulphur oxides from total fossil fuel use took place in all three countries depicted here over the period since 1970, but that this decoupling was much more pronounced in Japan than in other countries, as a consequence of very strict environmental standards promulgated in Japan during the early 1970's. The corresponding curves for nitrogen oxides show that for the USA and France (and for a number of other industrialised countries) the emissions of NOX have stayed in line with, or even grown somewhat relative to total fossil fuel requirements. In Japan, once again as a consequence of a vigorous control programme, nitrogen oxide emissions have been significantly reduced relative to fossil fuel consumption.

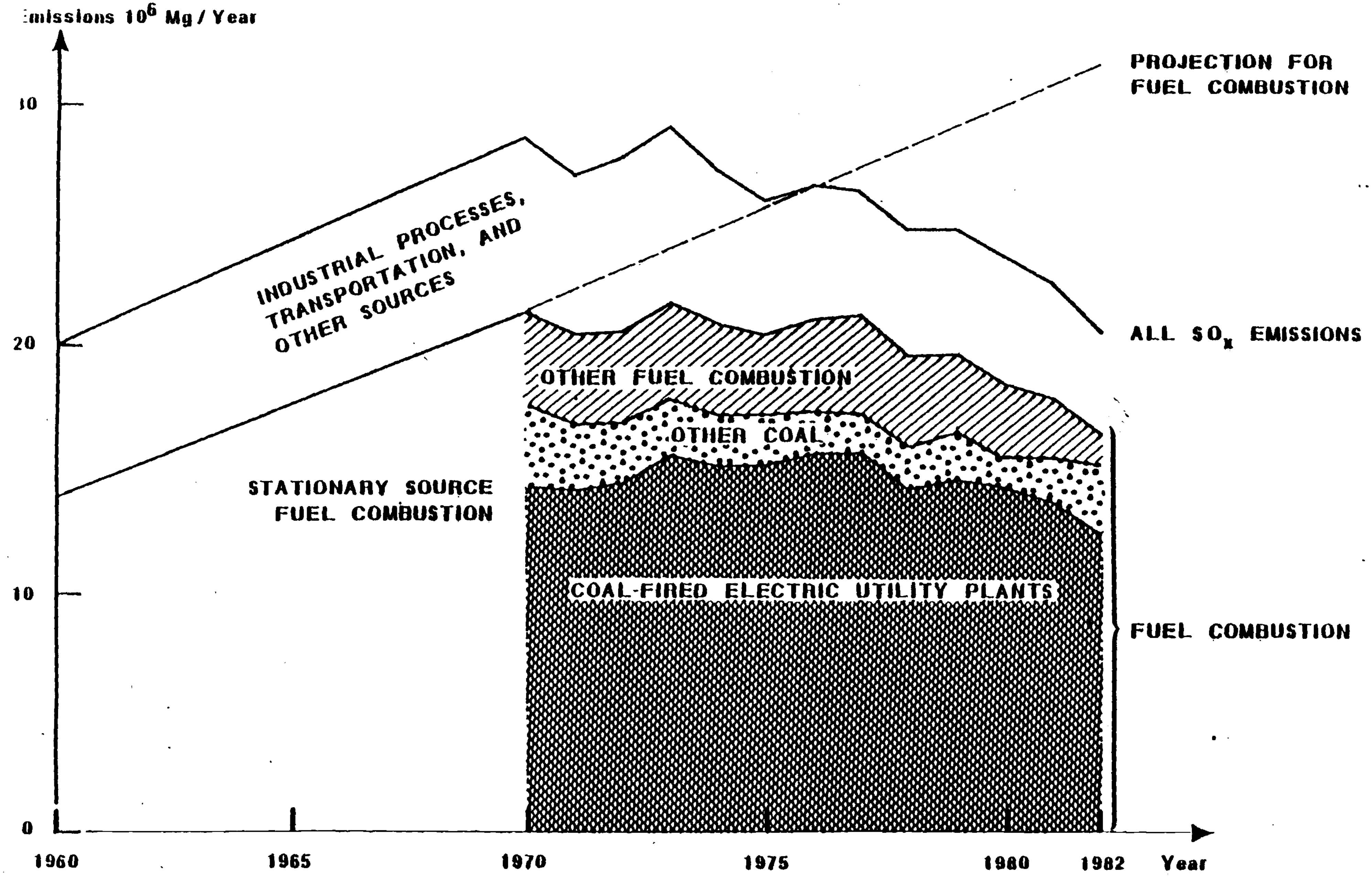
These are of course total national emissions. In order to develop strategies to reduce them it is necessary to have a breakdown among the principal sources. Figure 5 (a) and (b) show such a breakdown for sulphur and nitrogen oxides for the United States. It can be seen from Figure 5(a) that while SOX emissions from coal-fired power plants have declined somewhat since 1970, they still occupied 62 percent of total emissions of this pollutant in 1982, and the major part of the total reduction of 26 percent in national SOX emissions over this period can be attributed to combustion of other fuels (principally because of regulations limiting sulphur content of oil products). For this reason coal-fired power plants would be a major part of any strategy aimed at further substantial reduction of sulphur emissions in the USA.

Figure 5(b) shows that the transportation sector is the largest single source of NOX emissions, but that once again coal-fired power plants are responsible for a quarter of the total emissions. These two sectors would therefore be prime targets for any NOX emission reduction strategy.

There are of course variations in the patterns and trends of emissions from one country to another, and these are shown in the detailed figures given in Annex 1 for SOX and NOX emissions from selected OECD countries for the period 1965-1983. The same Annex

FIGURE 5(a)

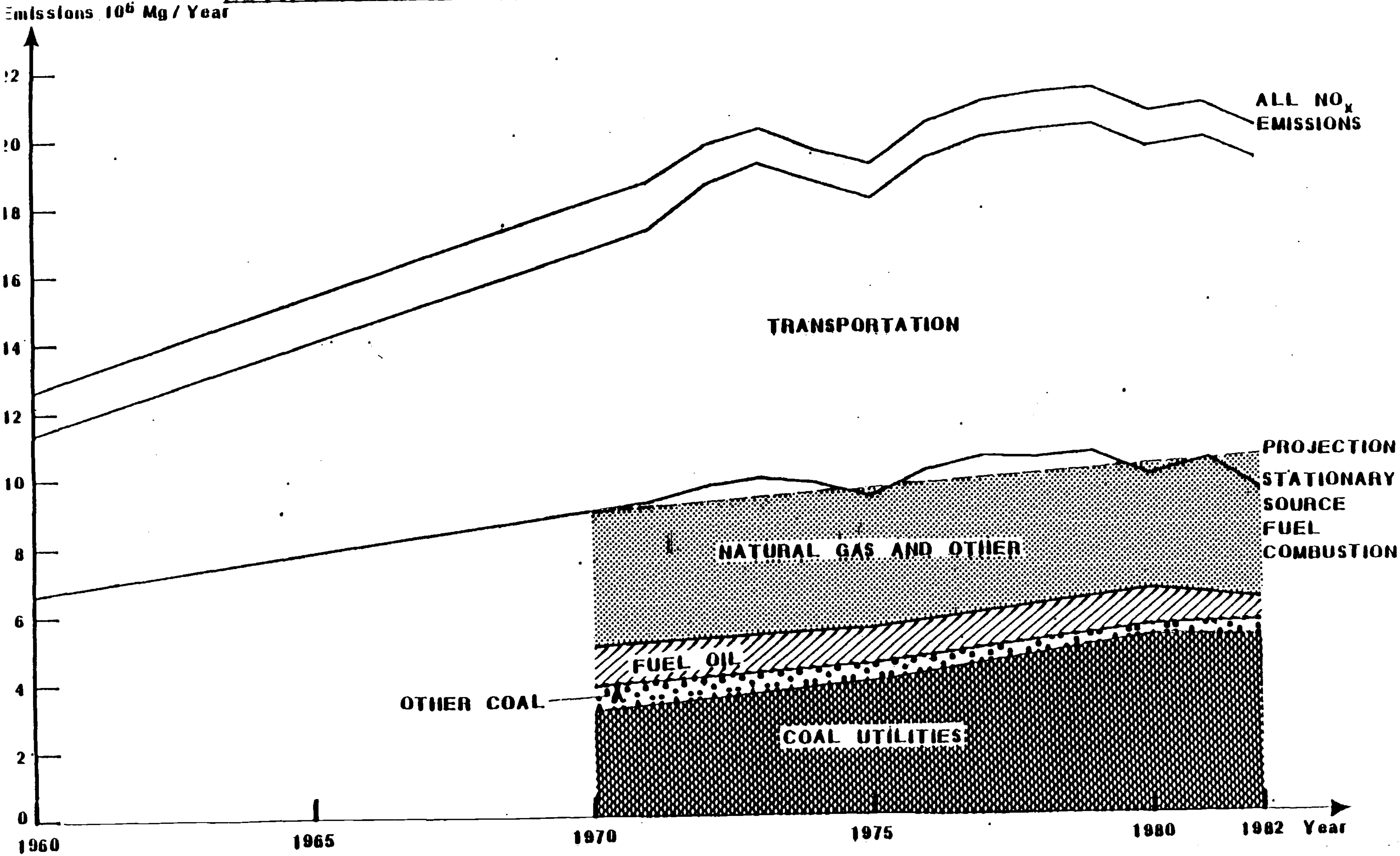
ESTIMATED U.S. EMISSIONS OF SOX BY SOURCE TYPE



Source : US EPA / OAQPs, *National Air Pollutant Emission Estimates, 1940-1982*, February 1984.

FIGURE 5(b)

ESTIMATED U.S. EMISSIONS OF NOX BY SOURCE TYPE



US EPA / OAQPS *National Air Pollutant Emission Estimates, 1940-1982*, February 1984.

also shows trends in consumption of the different primary energy sources by OECD countries and regions for the period 1973-1983.

VII. WHAT DO WE KNOW ABOUT ACID RAIN?

We do know that what goes up must come down! The precise form and the precise location are still subject to some uncertainties, but the very considerable amount of research which has been devoted to the science of atmospheric transport and deposition in recent years has begun to narrow the uncertainty. For example, we now know that:

With regard to deposition in general:

- In Western Europe and Eastern North America, acid deposition is about two-thirds sulphur and one-third nitrogen compounds;
- A substantial part of nitrate deposition is neutralised by plants, so sulphur compounds provide about four-fifths of acidifying deposition;
- However, in winter, when plant growth is halted, nitrates contribute more to total deposition, and in mountainous regions in particular, they contribute more to the "acid shock" following springtime snowmelt;
- Accurate estimates of how much deposition at a particular location stems from emissions from specific sources (the "source-receptor relationship") are not yet available;

With regard to sulphur deposition:

- Dry deposition, predominantly as SO2, is a substantial part of total sulphur deposition, and is proportional to the level of SO2 emissions;

- Wet sulphur deposition, mainly as sulphuric acid, is proportional to SO2 emissions on an overall regional basis for Eastern North America;
- Over Europe as a whole, deposition rates are not linearly proportional to SO2 emission changes, though linearity is found over smaller areas;
- Dry deposited SO2 on living ecosystems is transformed rapidly to sulphate, so that the majority of sulphur deposition on these systems shows a linear relationship with emissions;
- Dry deposition due to emissions from a particular source are greater than wet deposition due to the same source near the source (sometimes up to 12:1 in areas of high pollutant concentrations), becoming less than wet deposition beyond some 300 km;
- Wet deposition of sulphate aerosol is of most significance in areas of high rainfall far from emission sources, at distances of between about 500 and 800 km in prevailing wind directions;
- Recent work has found extremely high deposition from clouds onto forested mountain areas they rest upon;

With regard to nitrogen deposition:

- NOX and its compounds do not travel as far in the atmosphere as sulphur compounds, and consequently more is dry-deposited;
- This is confirmed by the fact that whereas oxidation of NOX to nitrate is faster than oxidation of SO2 to sulphate, little particulate nitrate is detected in the atmosphere;
- Although the proportion of nitric acid in precipitation has been increasing over the past decade or two in response to increased NOX emissions in a number of countries, the proportionality of dry deposition of nitrogen compounds to the amount of NOX emissions is less clearly established than for sulphur;
- The relative ranges of wet versus dry deposition of

nitrogen compounds are not as well understood as for sulphur compounds, because of the greater complexity of NOX transformations in the atmosphere;

- The deposition rate of ammonium compounds arising mainly from volatilisation of ammonia from arable soils has increased parallel to the use of nitrogen fertilisers in agriculture.

VIII. EFFECTS OF ACID DEPOSITION AND RELATED AIR POLLUTION

Acid rain, and/or air pollution in more general terms, is suspected of affecting lake ecosystems, crops and plants, forests, man-made materials, and human health. The following summarises the effects as presently understood.

1. On Aquatic Ecosystems

- Widespread loss of fish populations has been reported for sensitive lakes in Scandinavia and Eastern North America;
- The sensitivity of waters depends, as well as on pH, on their alkalinity (or bicarbonate concentration), which determines their acid neutralising capacities;
- The type of vegetation and the nature and depth of soils are also important in determining effects on waters, because they interact with deposited substances before they reach the waters;
- Short-term events, in particular the "acid shock" caused by springtime snow-melt, may play an important role in the damage to fish populations;
- The association of aluminium peaks with acid events in lakes and streams suggests that aluminium toxicity may be a factor in fish population decline;
- Also, calcium is less common in low pH water, and this can cause sometimes fatal imbalances in fish;
- There is uncertainty as to the time it would take a lake to adjust to a change in acid deposition rate, ranging from a few years to a number of decades.

On Crops and Plants.

- Studies to date give little reason for concerns about the effects of acid deposition alone on agricultural crops; indirect damage through acidification of soils is usually mitigated by the practice of liming the land for many crops;
- Ozone and other photochemical oxidants have been demonstrated to cause significant crop damage;
- There are questions about effects on soils, particularly their cumulative ability to absorb sulphate ions over a lengthy period and the effects on the soil's reserves of calcium and magnesium;
- Sulphur compounds can have a direct impact on plant foliage and stems or an indirect impact via the root environment; at lower concentrations than are associated with visible injury, sulphur deposition may limit plant growth and otherwise affect the health of vegetation;
- Most nitrate deposited is disposed of by the plants, but some studies point to increased nitrate leaching as a result of increased deposition;
- Interactions between sulphur and nitrogen compounds and other pollutants such as ozone or heavy metals can lower the resistance of vegetation to other environmental stresses such as drought or disease.

On Forests

- There has been serious and increasing damage to forests in the Federal Republic of Germany and other European countries (Switzerland, Austria, Eastern France, Czechoslovakia) in the past several years;
- Growth declines, as evidenced by tree ring spacing, have affected a number of tree species in parts of Eastern North America; a reduction in the growth of red spruce in Vermont and New Hampshire (USA) over the past two decades has been observed; more recently there has been extensive decline and death in red spruce in these states as well as some in New York and North Carolina;
- Scientists agree that air pollution plays a significant role in forest decline but do not know the extent of the damage due to acid deposition, ozone or trace metals;

- Ozone has well-documented effects on forests;
- Acid deposition and other air pollution can affect both the leaves (or needles) and the roots of trees (via the soil);

- The foliage of coniferous forests in particular has a high aerosol-capturing capacity, thus they receive more acid deposition than non-forested land;
- Though forest soils are generally acidic, they contain relatively weak organic acids, by contrast to the strong mineral acid contribution coming from deposition;
- Mobilisation of aluminium and heavy metals is of especial concern; the pH of forest soils in temperate regions is often at a level where an additional small pH decrease can cause a rapid increase in the mobility of certain of these toxic metals;
- In the Federal Republic of Germany "die-back" of spruce has been associated with deterioration of fine feeder roots in soils with high concentrations of mobilised aluminium and heavy metals;
- Leaching of calcium, magnesium and potassium from forest soils through acid deposition may lead to a long-term decrease in their fertility;
- Nitrogen deposition, in the form of nitrate and ammonium, is ten times greater in many European forests than would be expected in the absence of air pollution. This nitrogen may be providing temperate forests with excessive nitrogen which, while speeding up growth, may stresses;
- Concerns have been expressed about deposition of ammonium on forests situated in regions where intensive agriculture is practised;
- There is increasing concern that acidification of forest soils may occur in several stages, with visible damage to trees becoming evident relatively suddenly in the final stage after many years of acid deposition.

<u>On Materials</u>

- Sulphur compounds are corrosive to limestone, marble and sandstone structures, forming gypsum, which dissolves easily in water;

- Corrosion also affects metallic structures, principally those made of galvanised and painted steels;
- Nitric acid is particularly damaging to metals, forming highly soluble nitrates;
- The corrosive action of acidifying compounds is a mostly local phenomenon as distinct from being a consequence of long-range transport;
- Of especial economic and cultural importance are historical monuments, which are irreplaceable and whose value cannot be estimated;
- Atmospheric ozone damages paints and plastics, and reduces the durability of rubber.

On Human Health

- Concern centres mainly on indirect impacts, through contamination of fish by increasing their mercury content, and through heavy metal contamination of drinking water;
- Acidification of groundwater used for drinking purposes can lead to mobilisation of metals, principally lead, cadmium and copper from piping used, and aluminium from the soil;
- Ozone is strongly suspected of harming human health.

On Visibility

- Sulphates in the atmosphere contribute to reduction in visibility, through haze, particularly in regions of long-lasting stable temperature distribution and high relative humidity.

IX. POLICY CONCERNS AND FACTORS AFFECTING DECISIONS

The principal uncertainty, as Section VIII. has underlined, lies in the quantification of the damage to the various parts of the environment which can be attributed to a given amount of acid deposition or a given exposure to air pollutants. This is the so-called "dose-response problem".

And if there is uncertainty as to what has happened in the past or what is happening at present in the form of damage, there is even greater uncertainty about the future. One of the most critical factors is whether or not the damage is cumulative. Is what we observe now (e.g. in forest damage) the true extent of the effects of past and present levels of air pollution on the environment, or is latent damage accumulating in other regions and to a greater extent than is presently recognised? For example, does the discovery of declines in growth of some tree species in Eastern North America foreshadow the same type of forest damage which has been found in extensive areas of Europe?

The response of the environment to measures taken to reduce air pollution also depends on whether or not these effects are cumulative. One can easily imagine a situation where several years, and in some cases decades, might have to elapse before the benefits of policy action manifest themselves in the recovery of some of the affected ecosystems. This may mean that the industrialised countries have to face the prospect of paying to reduce pollutant emissions and paying the costs of environmental damage <u>simultaneously</u> for a period of years or in some cases decades.

The policy debate in industrialised countries therefore centres around whether it would be wiser to take action promptly by establishing stricter emission controls on acidic gases, or to wait until scientific research produces more evidence of actual or impending damage. The principal arguments of those who advocate delay in further policy action are:

- the risk of taking action which requires substantial expenditure and which may later be demonstrated by research to have been unnecessary;
- the possibility of developing less costly methods and technologies for emission control within the next decade.

The principal argument for rapid action, in addition of course to the actual damage already sustained, is the potentially accumulative nature of ecosystem effects of air pollution. In particular, the danger that some damage could prove to be virtually irreversible is of particular concern. Proponents of rapid action point out that even after passage of stricter control measures, the unavoidable delay in their implementation means that reductions in emissions consequent on these measures will only begin to occur several years later - for example, it takes some three years to design and build a flue gas desulphurisation plant, and more than a decade to renew an automobile population. A third argument for rapid action comes from the time which scientific experts estimate may be necessary for research to provide answers to some of the most significant questions: in the United States this has been estimated to be several years for effects on aquatic ecosystems and a decade or longer for forest effects.

In theory, of course, it should be possible to base policy decisions on the best estimate of the costs versus the benefits of specific actions to reduce air pollution. But the scientific uncertainty mentioned at the beginning of this section makes cost-benefit analysis of limited value in determining appropriate levels of control of air pollutant emissions. An OECD study (4) on the costs and benefits of sulphur oxide control, published in 1981, concluded that while there seemed to be a broad balance between costs and benefits up to quite high levels of emission control, the range of uncertainty of the benefits (or environmental damage costs) in money terms was extremely large - much too great to permit policymakers to zero in on any particular level of control. The large amount of cost-benefit analysis which has followed this work, mainly in the USA and Europe, still runs up against the same problem (5,6).

Consequently, policymakers are faced with a three-way choice: can we afford to wait for the results of further research and assessment; should we on the other hand insist on substantial reductions in emissions using best available control technologies; or should we at least take out some type of insurance policy in the form of a carefully designed programme aimed at a point where the cost-effectiveness curve turns sharply upward?

To make such a policy decision requires at least some reliable information on the technological state of the art and on the costs of emission control (and on the trends of these costs). It also requires an objective look at what the acceptance of these costs may mean for the national economy. What can be done to control the emissions leading to air pollution and acid deposition and what does it cost? The next Section will try to answer these questions.

X. HOW CAN AIR POLLUTION BE REDUCED?

No country would be willing to reduce air pollution by reducing economic activity generally. However, some industrialised countries have in the past decade or so, whether or not as a matter of policy, shifted their industrial structure away from heavier and more polluting industries, or out of manufacturing and into services. This type of structural change can have an important effect on air pollution. For developing countries the pattern of growth - particularly the role to be played by heavy industry - can also determine the seriousness of pollution problems they will face in the future. The economic structure question is of considerable complexity and goes far beyond the air pollution issue. It will not be further explored in this paper, except indirectly insofar as energy consumption and energy intensity of the economy are concerned.

Excluding these structural shifts, therefore, strategies to reduce acid deposition and related air pollution can take two basic forms:

1. MORE RESORT TO ENVIRONMENTALLY FAVOURABLE ENERGY OPTIONS

In this basically preventive strategy the objective is to reduce emissions by reducing the amount of pollutants produced in the first place, through for example:

(a) increasing the efficiency of energy use and thereby reducing the amount of fossil fuels required for a given level of economic output;
(b) substituting fossil fuels by non-fossil energy .

2. BETTER PREVENTION AND CONTROL OF EMISSIONS

Pollution control can involve more than just preventing gaseous emissions from leaving the smokestack or the car exhaust. Possibilities to reduce emissions include:

(a) use of lower sulphur fuels and fuel cleaning;
(b) improvements in the fuel combustion process;
(c) post-combustion cleaning of the exhaust gases.

In the following Sections we shall elaborate on these two types of approaches, which are of course perfectly compatible with each other.

XI. ENERGY OPTIONS TO REDUCE AIR POLLUTION

1. Energy Efficiency

In Section VI. it was noted that in a number of industrialised countries there had been a significant degree of decoupling of emissions of major air pollutants, particularly those of sulphur dioxide, from economic activity as measured by GDP. The causes include pollution control measures taken by governments and in some cases a shift in industrial structure away from heavier more polluting industry. But one important contribution to reduced air pollution is provided by changing patterns of energy production, conversion and use. Total energy consumption per unit of GDP has been substantially reduced over the past decade (see Figure 4), principally as a result of the large increases in energy prices which have stimulated measures to increase efficiency and reduce waste in all sectors of energy use. Less total energy means less air pollution, and the environmental benefits can and should be considered on a par with the energy and economic benefits of increased energy efficiency as a reason for maintaining an emphasis on this line of policy in the future, even in the event of a continued decline in the real price of energy.

2. Fuel Substitution

In addition to improvements in efficiency of energy use, energy policy in many industrialised countries has emphasised a shift away from oil for electricity generation and other major industrial uses. The net effect on the environment of such a shift of course depends on what energy sources take the place of oil. In the electricity generation sector the place of oil is most often taken by coal or nuclear power. New coal-fired power plants can be built with adequate emission controls (see next Section) in which case they may produce considerably lower emissions of acidic gases than many existing oil-fired power plants. But unless environmental regulations prescribe the use of state-of-the-art technology to achieve emission control standards, the danger is that power plant operators would avoid the more expensive control technologies in the interests of cutting costs.

For many uses, particularly in smaller and more dispersed units such as residential and commercial heating installations, natural gas, if readily available, may be substituted for more polluting fossil fuels, leading to lower emissions of both sulphur and nitrogen oxides.

Switching from oil to nuclear power clearly reduces the emissions of acidic gases, and is one of the principal strategies for power generation in some industrialised countries. However, in other countries nuclear electricity development has run into public opposition on grounds of potential safety and radioactive waste disposal problems.

3. Renewable Energy Sources

A number of renewable energy options have the potential to substitute for the use of fossil fuels to a certain extent. With the exception of hydropower, however, their potential total contribution on an economic basis in most countries remains quite limited.

4. Environmentally Favourable Energy Options

The OECD council has recently adopted a Recommendation on Environmentally Favourable Energy Options and their Implementation, aimed at achieving better integration of energy and environmental policies by identifying and promoting energy options which are supportive of current environmental goals. The Recommendation includes a set of "Elements of Environmentally Favourable Energy Options" which are reproduced in Annex 2 of this paper.

5. Enhanced Institutional Linking

One of the principal means of achieving better energy/ environment integration is enhanced institutional linking, i.e. closer cooperation, at an earlier stage in the policy process, between those in government responsible for energy questions and those responsible for environmental protection. Sometimes, those in government and industry concerned with energy supply have tended to perceive environmental concerns as adding to energy costs, or as problems which can be left to be resolved by those responsible for the environment after the basic energy decisions have been taken. There are clearly exceptions to such a general observation. Nevertheless, the relationship between environmental constituencies and those responsible for investment decisions in the energy supply sectors has not always been as positive and constructive as would be desirable.

Some examples may be cited of the ways in which this institutional cooperation could and should be strengthened to the benefit of both parties (see Annex 2). These include joint promotional initiatives especially for energy efficiency improvements, cooperation on government-sponsored R and D projects aimed at "cleaner energy", and better three-way communication between the government departments concerned for energy and environment and industries involved in energy investments and pollution control manufacturing.

6. Integration of Environmental Costs in Energy Prices

Another important element in promoting environmentally favourable energy options concerns the integration of environmental costs in energy pricing and incentives. In any situation where energy prices are regulated or otherwise controlled, there exists a potential for distortions in the economic process of paying the costs of environmental clean-up and protection. When environmental costs are fully reflected in energy prices, those sources of energy that are more favourable to the environment will be more attractively priced than those with high environmental costs. For example, gas is normally more expensive than coal, but the gap is narrowed when the full costs of adequate environmental protection are included in the price of coal-based energy.

7. Incentives for Environmentally Favourable Investments

Incentives such as tax credits or grants are used in some countries to achieve energy goals such as fuel switching away from oil, or upgrading building insulation to save energy. But there are few incentives to make environmentally favourable energy investments on environmental grounds, whereas in some instances the environmental benefits alone might provide sufficient justification for such government incentives.

8. Environmentally Favourable Energy Technologies and Measures

Annex 2 also contains a comprehensive table taken from the background document to the OECD Recommendation (now derestricted and in the process of publication), which provides an overview of a number of environmentally favourable technologies and measures, including their potential environmental and energy benefits, the timescale for commercial application, impediments they face, and main policy options for encouraging them.

Clearly the concept of Environmentally Favourable Energy Options goes well beyond the topic of this paper in its scope and potential. However, most of the ideas contained in the "Elements" are directly applicable to the narrower objective of reducing air pollution. Also, while these ideas were developed in the OECD context, they are certainly relevant to the situation of other countries, particularly those whose process of industrialisation and economic development is at an earlier stage.

XII. BETTER PREVENTION AND CONTROL OF EMISSIONS

Reliable technologies and methods exist for achieving a high degree of control of the major air pollutants from most sources. More than 99 percent of particulates and hydrocarbons, up to 95 percent of sulphur oxides, and 90 percent of nitrogen oxides can be removed from flue gases in large installations by one or a combination of methods. Various technologies and methods can remove up to 90 percent of NOX, hydrocarbons and carbon monoxide (CO) from vehicle exhausts. Table 1 lists some of the applicable technologies and methods and gives an indication of their effectiveness. Annex 2 also includes some technical principles

TABLE 1

AIR POLLUTANT EMISSION REDUCTION TECHNOLOGIES

Pollutant	Control Technology	Effectiveness
(a) Stationary Sources		
SO_x	Fuel selection	Depends on S content
	Coal cleaning	Depends on fuel quality: up to about 30% S removal for coal
	Distillate oil desulphurisation	Can reduce S content to 0.15% by weight
	Fuel oil desulphurisation	Usually not competitive with FGD
	Limestone injection in combustion chamber	Up to about 60% S removal
	AFBC	Up to 90% S removal
	Flue gas desulphurisation (FGD)	Up to 95% SO_2 removal
NO_x	Combustion modifications	Up to 60% NO_x reduction
	Flue gas denitrification (Selective catalytic reduction)	80% NO_x removal
HC	Condensers	85 to 99% HC reduction
	Carbon adsorption	35 to 99% HC reduction depending on process
	Incineration	90 to 99% HC reduction
(b) Mobile Sources		
NO_x	Exhaust gas recirculation (EGR)	50% reduction
	Lean combustion with EGR	Up to 85% reduction
	3-way catalyst	50 to 90% reduction
HC	Lean combustion with EGR	25 to 50% reduction
	3-way catalyst	60 to 90% reduction

extracted from a recent OECD Recommendation on control of air pollution from fossil fuel combustion. An important point is that pollution control technologies have been improving very rapidly in reliability and effectiveness in recent years, and this trend is likely to continue or even accelerate.

1. <u>Power Plants and Large Industrial Installations</u>

Some technologies were developed quite recently and were either not available (e.g. flue gas denitrification) or were considered not suficiently reliable (e.g.flue gas desulphurisation) to be required for installation in large combustion plants in most industrialised countries in the past. This in fact is the cause of an important part of the controversy over emission control at present. A large fraction of total emissions of acidifying pollutants in some countries comes from some older combustion installations such as power plants which do not meet the emission

control requirements an equivalent new plant would be required to meet in the same country. The question is whether these plants should be required to retrofit pollution control requirements. This is further explored later in the paper, in Section XV.

<u>Smaller Industrial Installations</u>

Pollution control in smaller plants of the size used by industry is economically more difficult than for large power plants, since they can derive fewer economies of scale. To date these plants have relied for pollution control less on combustion and post-combustion clean-up than on choice of fuel and fuel treatment. Here, there are indications that new technologies, recently developed or now under development, may hold good promise for the future. Atmospheric fluidised bed combustion (AFBC), now being offered commercially by an increasing number of manufacturers, gives smaller boilers the capability of up to 90 percent sulphur removal in the combustion process, through limestone injection. AFBC also increases greatly the range and variability of quality in the fuels which may be used in industrial boilers. Another new technology, limestone injection in multistage burners (LIMB), again aimed at reduction of sulphur and nitrogen oxides leaving the combustion chamber, is presently at the pilot plant stage. Both of these technologies are being scaled up in test facilities in the United States and the Federal Republic of Germany, with the objective of assessing the possibility of applying them to electricity generation plants.

3. Vehicles

As far as mobile sources are concerned, pollution control is mainly aimed at nitrogen oxides and hydrocarbon emissions. There is to some degree an interplay among the principal pollutants emitted by vehicles. In the past, measures to reduce emissions of carbon monoxide, harmful to human health in urban areas, led to increased emissions of other pollutants. Reduction of combustion temperatures to reduce NOX emissions leads to more unburnt hydrocarbons being emitted. Thus to reduce simultaneously all major air pollutants from vehicles usually requires some post-combustion control equipment.

The three-way catalytic converter, now used in North America and Japan, reduces emissions of nitrogen oxides, hydrocarbons and carbon monoxide to a small fraction of their uncontrolled level (and requires lead-free fuel to avoid destroying the catalyst). Other technologies now under development to reduce one or another of these pollutants (e.g. the "lean-burn" engine or the stratified charge engine) are also aimed at increasing fuel efficiency -- itself a means of reducing pollutant emissions. Judging from past experience, the requirement to meet lower pollutant emission standards can be a powerful stimulus to develop more efficient and effective technologies for both combustion and exhaust gas clean-up.

XIII. COSTS OF EMISSION CONTROL TECHNOLOGIES

1. Uncertainties in Cost Estimation

With a wide range of possible control technologies and methods applicable to an equally wide range of emitting installation, there is clearly a high degree of uncertainty in any estimates of the control costs. Recent work on coal pollution abatement has highlighted the problems of cost estimation, especially in comparing estimates across countries (7,8). One fundamental difficulty is the question of what may be specifically termed "environmental control". Other problems in comparing cost estimates for specific pollution abatement technologies arise because of differences in methodologies and assumptions employed by different authors and organisations. For example, air pollution abatement costs depend on a number of key physical parameters (related primarily to fuel characteristics, power plant design, and applicable regulatory standards), as well as on various economic parameters that strongly effect capital and operating cost calculations. Lack of a standardised methodology and nomenclature for identifying and reporting all elements affecting cost calculations inevitably hinders the ability to assure that any comparisons that are made are systematic, and reflect a consistent set of premises. The OECD, with the help of some experts from both government and industry, is currently involved in an exercise designed to produce a recommended list of physical and financial parameters which should be clearly specified in any control cost estimate (or any report of actual control costs for a specific installation), in order that such an estimate should be useful to other cost analysts.

2. Power Plants

Recognising the above difficulties, it is still possible to highlight the relative importance of control costs for different air pollutants. We do so by selecting as a specific example the case of a new coal-fired power plant and giving some cost ranges drawn from recent experience and estimates (Table 2).

The uncertainties mentioned above are perhaps best illustrated by the case of flue gas desulphurisation (FGD), the most costly of the control technologies and the one with the widest range of estimated costs (see Table 2). A careful analysis of the many different factors, both hardware and financial, which enter cost estimates in several major Industrialised countries, has revealed important real differences in the capital cost of FGD in the United

TABLE 2

INDICATIVE AIR POLLUTION CONTROL COSTS IN A NEW BASELOAD COAL-FIRED POWER PLANT

Pollution and Control Method	Capital Cost	Annual Total Cost (capital and operating)		Operation and Maintenance
	$/kW	mills/kW	% of cost of electricity generated	(% of Annual Cost)
Particulate Control				
-- ESP	15-40	1-3	1-3	25-55%
-- Fabric Filter	25-50	2-4	2-4	
Sulphur Oxide Control				
-- FGD (entire flue gas stream)	70-185 (1)	5-12 (1)	9-16 (1)	35-70%
Nitrogen Oxide Control				
-- Combustion Modifications	5-15	1-2	1-2	
-- Flue Gas Denitrification (2)	35-85	2-6	3-5	50-80%

1. The range given here for FGD is very broad. The capital costs reported in OECD countries for FGD at 90 per cent efficiency of sulphur removal applied to the entire flue gas stream, mostly fall in the range of $140-$185/kW for the USA, $90-$150/kW of installed generating capacity for Japan, and $70-$130 for Europe.

2. Experience in flue gas denitrification is still limited, being applied in full-scale coal-fired installations only in Japan.

States as compared with Europe and Japan. While the strength of the US dollar and the higher real interest rates in comparison with the currencies and interest rates of other countries are significant factors, a major part of the cost variation appears to arise from the very different approaches to the configuration ofthe FGD system in the USA as compared to elsewhere. Early difficulties with FGD reliability, combined with regulatory requirements, led the United States utilities to adopt the modular approach: typically, for a 600 MW power generating unit, four separate FGD units would be built, plus one spare unit (i.e. 20 percent redundancy). This configuration is still the practice in the USA, though many of the reliability problems have been largely resolved through experience and improved maintenance and control.

In Europe and Japan, on the other hand, the practice adopted has been to build one single FGD unit capable of handling the entire flue gas stream, with little or no redundancy. This leads to very significant economies of scale in contruction (one unit instead of five), as well as a reduction in construction time (hence in interest during construction). Other differences include engineering contingency charges (high in the USA and lower elsewhere). What is emerging is a rather different range of FGD costs for the US situation and for other major OECD countries, as indicated in the footnote to Table 2.

To go into this degree of detail on the specific item of FGD cost comparisons may seem unnecessary in a paper such as this, but it must be remembered that FGD is a highly significant item in the curent international debate on acid rain and air pollution, mainly because of its reputedly high cost. Consequently, any information or insight which indicates the possibility of a sizeable downward shift in its cost would alter the terms of reference of that part of the debate.

3. <u>AFBC and LIMB</u>

Fluidised bed combustion provides a lower cost pollution control method for smaller industrial boilers (below about 100 MWth) than the installation of FGD. The picture becomes less clear as the boiler size increases, because application of AFBC to units of the size which could be used in power plants is only now reaching the demonstration stage. This technology may turn out to be advantageous for the smaller end of the range of generating units, but it is not likely to be competitive with FGD for the size of boilers (200 MWe and greater) normally used in central electricity generating stations.

The LIMB technology being even newer and less completely tested, it is difficult to be certain of its competitiveness for different size boilers. The available cost estimates based on small scale pilot studies indicate lower costs per unit of installed capacity or of heat or electricity generated. But when the lower efficiency of sulphur removal for LIMB than for FGD is included in the comparison, the cost advantage of LIMB in terms of cost per unit of sulphur removed becomes marginal, especially considering that the technology cannot yet be said to be a proven one. An additional complicatiion of LIMB is that in the event of operating problems the entire boiler has to be shut down, since the technology is part of the boiler (as opposed to an FGD unit, which is a separate piece of equipment). Further operating experience with LIMB, especially in larger boiler sizes, will be necessary to obtain a reliable asessment of its competitiveness.

4. <u>Vehicles</u>

The problems associated with estimating the costs of pollution control applied to vehicles are if anything more complex. If emission reductions are achieved through specific add-on equipment, the cost situation is clearer: the three-way catalytic converter to reduce emissions of NOX, HC and CO costs approximately \$300 - 500 per car, when other necessary modifications to the propulsion system are taken into account.

But a great deal of R and D by the motor industry has been devoted over the past decade to achieving a simultaneous reduction of the amount of pollutants emitted and the vehicle fuel consumption. It is difficult to assess how much additional cost to attribute to the gradual improvement in vehicle energy/environment performance, and particularly how much of this cost should be allocated to pollution control. The "lean-burn" engine is now being developed in a number of countries as a promising way to meet stricter emission standards, especially for smaller cars. It reduces emissions of NOX but not of unburnt HC. However, in association with an oxidation catalyst (simpler than a three-way one), significant reductions in both NOX and HC could be achieved. How much of the cost of a lean-burn engine is an environmental control cost is an almost impossible question to answer.

XIV. AGGREGATE COSTS OF POLLUTION REDUCTIONS

If the estimation of pollution control costs is complex for a single plant or vehicle, a much higher degree of uncertainty applies to estimates of the cost of acid rain control strategies at the national or international level. Again taking the example of the power generation sector, among the sources of uncertainty, even given the constancy of environmental regulations, are the difficulty of assessing the future economic or electricity demand growth; the rate at which new generating capacity comes onstream and old capacity is phased out; and the uncertainty in predicting when technological improvements will be available for commercialisation and at what cost.

1. Stationary Sources

Notwithstanding these difficulties, overall estimates have been made for the costs of control strategies for SOX in Europe and the United States (5,6,9-13). These include the installation of pollution control equipment on both new and existing power plants and major industrial installations. Table 3 gives an order of magnitude. The numbers shown here are of course large - of the order of billions of dollars over a period of a decade or so. But we should try to get them into the perspective of what they would mean for the electricity consumer. For example:

- In the German case, the emission reduction of Table 3 is

TABLE 3

COSTS OF STRATEGIES TO CONTROL AIR POLLUTANTS

Country or Group	Air Pollutant	Emission Source (Stationary)	Reduction	By Year	Annual Cost	Source
European Community	SO_2	all	10-13 M tonnes (53-77%)	2000	$4.6-6.7 bn[(1)(2)]	Ref. 5
	NO_x	all	50%	2000	$0.4 bn[(1)]	Ref. 5
Federal Republic of Germany	SO_2	all	1.6 M tonnes (50%)	1993	DM3.3 bn	Ref. 9
United Kingdom	SO_2	power plants	1.5 M tons (50%)	1995+	£175 m[(3)] (average)	Ref.10,11
United States	SO_2	power plants	10 M tons (75%)	1995+	$4.2-5.3[(1)]	Ref. 12
United States	SO_2	power plants	"	"	$5.2-9.5[(1)]	Ref. 13

(1) 1982 prices.

(2) Includes retrofitting FGD on 70% of large coal and lignite boilers over 25 MW.

(3) 1983 prices. Includes cost of replacement of output capacity lost through retrofitting of FGD. This accounts for about 25% of total capital costs of £1990 million sterling.

estimated to add about one pfennig per kilowatt/hour to the electricity price to consumers (or approximately 6 percent) (9);

- The United Kingdom Central Electricity Generating Board has estimated that retrofitting FGD to existing coal-fired power plants to achieve a 50 percent reduction in SOX emissions might add, over a period of more than a decade, about 5 - 6 percent in total to the average cost of electricity generated in the United Kingdom, and considerably less than this to consumers' electricity bills (12);

- A recent report issued in the USA places the average electricity generating cost increase nationwide caused by a 10 million ton annual reduction in SO2 emissions from power plants at about 3 - 4 percent (though some utilities might incur cost increases several times this high, since they have a large proportion of older more polluting plants) (6)

Increases of this magnitude are not negligible, but they are far from catastrophic. Because of the time which would be required to realise a programme of emission reduction, the electricity priceincrease would be spread out over a decade or so. In fact, over the past decade in most industrialised countries, consumers have been faced with far greater annual increases in electricity prices for reasons which have nothing to do with the environment, such as oil price increases or rising coal miners' wages.

2. Vehicles

A very different situation prevails in different parts of the industrialised world as regards vehicles, and it would be difficult to derive any comparable numbers for overall control costs. According to the US Department of Commerce (14), all controls of NOX, CO, HC and particulates from mobile sources cost $16.5 billion annually in 1981. These costs are the total for the approximately 136 million light and heavy duty vehicles in the USA in that year, giving an average of $121 per vehicle per year. Though this figure may seem high, it covers all costs of the mobile source air pollution control programme, including administration and enforcement, fuel maintenance, etc. added by the controls (but not R and D). This programme achieves reduction of over 90 percent of emissions from gasoline-powered engines, and reduces diesel emissions as well.

XV. ECONOMIC ISSUES AFFECTING POLICY DECISIONS

The previous Sections have set the stage for a discussion of the economic issues. As already pointed out, a great deal of current debate is focussed on the question of whether to incur the significant costs associated with a reduction in emissions of the major air pollutants even though the cost-benefit picture is not clear. Bound up in this question is a number of subsidiary issues which this Section will address.

1. THE APPROPRIATE LEVEL OF CONTROL FOR DIFFERENT SOURCES

Pollution controls are often more expensive for smaller combustion installations than for larger ones like power plants. If alterations such as better and less polluting combustion technologies are not available, there may be a case for applying less stringent emission standards to industrial boilers than to power plants. Whatever the standards are, however, they should reflect what is achievable by the best technologies economically feasible for such plants.

For mobile sources the picture is more complicated. Catalytic converters on smaller cars add a much larger percentage to the purchase price than they do for larger cars. But, in addition, uncontrolled smaller cars emit lower quantities of pollutants per vehicle-mile than do larger ones. A lot depends, therefore, on the emission limits set and on the most economical way that cars of different size can meet them. In fact, the choice of emission limit levels is crucial to the choice of technologies, and thus to the overall cost. In the 1970's, in the United States and particularly in Japan, governments set emission limit targets for future years which turned out to be "technology-forcing", and which were met by development of the catalytic converter and by improvement in fuel efficiency.

2. HOW TO TREAT NEW EMISSION SOURCES AND EXISTING SOURCES?

A perennial problem in industrialised countries is how to deal with polluting installations which were built in earlier times when control regulations were less strict or non-existent. Large installations in particular may have several decades of useful life still ahead, and yet may emit levels of air pollutants which are far in excess of those which a new plant would be allowed to emit -- for example, some older coal-fired power plants in the United States emit 10 - 15 times the amounts of SO_2 which an equivalent new power plant would be allowed to emit under the federal new source performance standards.

The philosophy adopted in most industrialised countries until recently was that it is not appropriate to apply pollution control regulations retroactively, requiring older plants to retrofit new equipment unless they are being significantly modified for another reason. However, new regulations in the Federal Republic of Germany, the Netherlands and Austria have in fact introduced retrofit requirements under certain conditions. A lively part of the current debate on air pollution concerns whether or not this approach should be adopted by other countries. Certainly, in a number of countries it would be difficult to achieve large reductions in emissions of SOX within less than a decade without a degree of retrofitting.

The argument for bringing existing installations under the umbrella of stricter control regulations applying to new plants is reinforced by the observed tendency, if the former remain under a separate control regime, for their operating lifetime to be substantially prolonged in order to save costs for their operators. It is significant that the average remaining lifetime for a power plant in the USA as estimated by the utilities was 25 - 30 years in 1970, and is presently 40 - 45 years. This may be partly due to a slackening in electricity demand growth and expected growth since 1970, but it is certainly due in part to the stricter pollution control requirements which would be placed on replacement plants.

3. WHO PAYS FOR INCREASED CONTROLS?

There is an easy answer to this question and a more difficult one. The easy one is to apply the Polluter Pays Principle, which says that the costs of preventing pollution should be borne by the polluter. For example, installing FGD in a power plant adds to the cost of the generator of electricity. Normally, the additional costs will be reflected in the electricity price paid by consumers.

The fact that policies to reduce air pollution generally affect a large number of individuals makes a distribution of costs and benefits a central issue in the analysis of the policy options. From the perspective of overall economic efficiency, it makes no difference who gets the benefits or who bears the costs. However, the benefits and costs accrue to different persons or groups, and society generally has a strong interest in who these persons or groups are. It often becomes necessary then to take care of income distribution by other policy measures.

In the above example, the electric utility may be far in distance from areas where the greatest environmental damage occurs, and if the cost of reducing pollutant emissions is passed through to electricity prices, the consumers who pay these increased prices are in many cases not the same as those who presently bear the costs of environmental damage (sometimes they are not even citizens of the same country).

Distribution of additional pollution control costs may affect individuals not only directly by increasing their electricity costs, but also indirectly by placing a greater burden on their region or country. In some cases this may be because that region or country tolerated more polluting practices than its neighbours in the past. But it can also be related to structural factors (more traditional manufacturing industry) or to patterns of fuel consumption. For example, according to some bills which have been introduced in the US Congress, a number of utilities in the Mid-West and South-East of the country, which depend on medium and high sulphur coal, would be required to incur greater pollution control costs (via retrofitting) than other utilities. This is estimated to have adverse effects, via electricity rate increases, on the region's manufacturing industry, much of which has already suffered greatly through loss of competitiveness in recent years. This is why some proposed bills include alternative suggestions of means of payment, such as a tax on all electricity generated in the United States.

4. HOW TO ACHIEVE THE MOST EFFECTIVE RESULTS AT LOWEST COST?

An unwritten principle of pollution control is that it is usually more cost-effective for regulations and standards to specify the end but not the means, e.g. to set the emission limits but not to specify the technologies or methods used to meet these limits. Of course such a clear distinction is not always very realistic in practice: emission limits must be fixed with an eye to the possible and economically feasible, which in turn demands some appreciation of what can be achieved by present technology and at what cost.

There are several different levels of specificity, however, ranging from a single plant or single vehicle up to total national emissions of a given pollutant. As we go up the scale, the degree of flexibility which is, in theory, possible in responding to a policy objective of pollution reduction becomes somewhat greater. An example of this is the so-called "bubble concept" which has been applied on a modest scale in the United States. According to this, emission sources of a single company (or within a limited geographic area) are considered to be enclosed in a conceptual bubble for the purposes of emission regulation. A target emission reduction, or a total emission limit based on some measure of production or fuel use within the "bubble", is set and it is left to the operator of the installations to decide how best to comply with it. A typical response might be to install a high degree of pollution control on one outlet and leave the others unaltered. When there is more than one operator, the bubble can be accompanied by some form of emission trading, whereby the operator of one installation may find it more economic to continue former levels of emission and share the cost of another operator's pollution control equipment.

Optimisation of strategies for air pollution control can also involve an integrated approach to the best technological and economic means to reduce emissions of air pollutants from different categories of installation. A good example is provided by sulphur emissions from coal burning. It may be efficient in some cases to use coal preparation in conjunction with other methods of sulphur control as a means of reducing overall atmospheric sulphur emissions. One feasible strategy is to wash coal to produce two products -- a clean product and a higher sulphur, lower quality product. The clean product could be used where the heavy investment for flue gas desulphurisation could not be economically borne by the user, in particular by the small scale user. The higher sulphur product could be used in large power plants, with FGD, where the required investment is possible.

5. ECONOMIC BENEFITS OF STRICTER CONTROLS

In Section IX. the difficulties in making quantitative estimates of economic benefits which occur as a result of avoidance of environmental or health damage were noted. While it is not possible to assert that the benefits of any action to reduce emissions would outweigh the costs, it is equally impossible to assert the contrary. Furthermore, the intangible nature of some of the effects (e.g. damage to historical monuments) makes conversion of some of these benefits to monetary terms impossible in such cases: nevertheless they are real.

A second economic factor on the benefits side, which is not often taken into account in the policy debate, is the stimulative impact which stricter environmental standards can have on economic activity and on technological development. R & D, and manufacturing pollution control equipment, contribute to economic progress, and in particular to GDP. They can also add to levels of employment in sectors which are working well below capacity. Finally, they can result in lowering both environmental control coast and other costs through technological advances (e.g. by development of more fuel-efficient automobiles).

XVI. AIR POLLUTION AND DEVELOPMENT

The problems of acid rain have been demonstrated to be problems of industrialisation - and more specifically, industrialisation without adequate attention to the environment. The industrialised countries over the past decade or two came to recognise the truth in the old adage "Prevention is better than cure". Some newly industrialising countries are presently coming to a similar conclusion. Unfortunately, it often seems to require serious environmental degradation or extensive health damage to stimulate effective action against air pollution. The problems facing many urban areas in the developing world today resemble more those which faced cities in the industrialised countries in the 1950's and 1960's - severe local air pollution and inadequate regulations - than they do the specific problems which gave rise to the acid rain debate, with its strong component of long-range transport of major air pollutants.

But developing countries stand to profit from industrialised countries' experience in this respect. In solving their local air pollution problems, the latter in fact created the acid rain problem. The most economic solution seen for the "London smog" problem and the like was at that time seen to be better atmospheric dispersion of the responsible pollutants through tall chimney stacks. Indeed, so long as the global absorptive capacity of the atmosphere is not exceeded (and we recall that for SO2, for instance, natural sources account for about half of total emissions worldwide) then atmospheric dispersion can be a valid policy if the implications for deposition far enough downwind are taken into acount. A tall chimney on an island or on the leeward side of a continent with no inhabited land downwind for 1000 or more kilometers is not likely to be responsible for environmental damage. But there are many situations in the developing world where increasing industrialisation has the potential for causing environmental problems "downwind" either in the country itself or in a neighbouring country.

One might cite the case of China, in a process of rapid and accelerating economic development, whose main indigenous source of energy is coal. A number of new coal-fired power plants are being constructed or are planned. Depending on the pollution control policies adopted for these and other industrial installations in China, there could be a substantial increase in sulphur oxide and nitrogen oxide emissions and long-range transport of these gases in Eastern Asia, which could become a source of some concern to China, Japan and other countries of the region. Other industrialising countries further south, for example Indonesia and Malaysia, may also add to the regional air pollution problem in the future, unless it is addressed and forestalled now by action to reduce, not to disperse, emissions which are likely to be deposited downwind in inhabited and/or environmentally sensitive areas.

There has been a tendency in the past for both industrialised and developing countries' policymakers in fields other than the environment to look on environmental protection as a constraint on economic development and as a luxury which only the richest countries could afford. The opposing perspective is to question to what extent countries can afford not to protect the environment. However, we have noted earlier that with regard to air pollution, at least at the levels now prevailing in most industrialised countries, it is difficult to assess unambiguously the benefit/cost balance of additional controls.

Perhaps a more fruitful perspective therefore, would be to view the situation of industrialising countries as an opportunity rather than a constraint - an opportunity to develop "cleaner" economies, where environmental considerations are better integrated from the outset in all sectors of the economy. This integration was, in fact, one of the main themes of the OECD Environment Ministers' meeting held in Paris on 18-20 June 1985. They recognised that this would be economically desirable, though it often poses difficulties of a practical and institutional nature.

What does "integration' mean for the developing countries in the context of air pollution? The integration of environmental and energy policies developed in Section XI indicates one avenue: developing countries can avoid some of the patterns of energy production, conversion and use which the industrialised world introduced during the period of cheap energy and which are slow to change once in place (a particular example being energy-inefficient buildings). They can integrate environmental considerations into their industrial development by adopting environmentally favourable industrial processes and "clean" technology. They can insist on emission standards for air emissions from electricity generators and other large industrial installations, which ensure the reduction of local and, where necessary, long-range air pollution. And they can control emissions from vehicles: this should become less difficult as the present move towards greater worldwide uniformity in automobile emission standards among industrialised countries becomes reflected in similar standards in emission control technology in new cars from all major motor manufacturers.

Developing countries will be helped in this effort if cooperation by industrialised countries and international organisations in the form of assistance or investment includes an environmental component. The present World Bank practice of including environmental impact assessment in major projects is a step in this direction.

All this may sound rather theoretical to policymakers in developing countries faced with massive economic obstacles to the achievement of their development goals. Indeed, the realisation of these goals without ensuing air pollution problems, as in most other areas of environment and development, will require substantial cooperation between industrialised and developing countries at both government and industry levels. Economically efficient prevention of air pollution from both stationary sources and vehicles requires technologies which are at present found only in the most advanced industrialised countries. And as mentioned earlier, pollution control is presently in a period of rapid technological advance in these countries, in response to the current trends towards tightening air pollution regulations.

In the context of greater environmental cooperation in general between industrialised and developing countries, this paper recommends in particular as regards acid deposition and air pollution:

1. That assessments be made of countries and regions of the developing world now, or likely in the future as a consequence of their economic development to be subject to environmental damage resulting from air pollution and acid deposition;

2. That these assessments highlight actual or potential transboundary air pollution problems;

3. That meetings at expert level under the aegis of an appropriate international organisation be convened to help provide up-to-date knowledge and expertise to developing countries concerning the mechanisms and effects of air pollution and the technical means to reduce it from all sources, both stationary and mobile;

4. That an advisory but action-oriented industry body be set up, consisting of senior executives from selected industrial companies in both industrialised and developing countries, with the principal task of advising on how best to achieve the transfer of clean industrial technologies and advanced pollution control technologies to developing countries;

5. That the installation of an adequate level of air pollution control (taking into account both local and long-range effects) should be a necessary feature of all projects involving loans, grants or other investments in developing countries.

XVII. A FINAL WORD

The air is a resource essential to human beings and to the rest of the living environment. Like all resources, its use can bring large economic benefits, but its abuse can be damaging, even though its absorptive capacity is great. Much work has been addressed to the quality of the air we breathe and to what levels of pollutants are damaging to human health. Only recently have we begun to address the question of the air quality needed to maintain an environment which is healthy for the ecosystem as a whole as well as for our own health and our future economic development. We are finding that some parts of this environment may be more sensitive than human beings are to current levels of man-made air pollution.

Given that we possess the technological capacity to reduce air pollution very substantially at a cost which is far from prohibitive, the balance of uncertainty facing the decision-maker may now be swinging towards action. A growing number of policymakers in both industrialised and developing countries now appear to be moving in this direction.

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ANNEX 1

SOME RELEVANT DATA

PRIMARY ENERGY REQUIREMENTS, BY ENERGY SOURCE

	CHANGES from 1973 to 1983 (in MTOE)				
	Coal	Oil	Gas	Nuclear	Hydro + others
CANADA	+17	-14	+2	+7	+16
USA	+105	-72	-112	+50	+14
JAPAN	+3	-43	+19	+26	+4
AUSTRALIA	+7	+2	+6		
FRANCE	-3	-33	+9	+30	+5
GERMANY	-3	-38	+12	+12	+1
ITALY	+3	-15	+8	+1	+1
SPAIN	+7	+5	+1	+1	
SWEDEN	+2	-10		+9	+1
UNITED KINGDOM	-22	-39	+18	+5	
North America	+160	-92	-109	+56	+22
OECD Pacific	+10	-41	+27	+26	+5
OECD Europe	-2	-156	+53	+66	+17
TOTAL OECD	+168	-289	-28	+148	+45

Note : MTOE = Million tonnes of oil equivalent

Reference : OECD Compendium 1985 (3)

EMISSIONS OF SOx, by source, selected countries, 1965-1983

EMISSIONS DE SOx, par source, pays sélectionnés, 1965-1983

1000 tonnes

Mobile Sources/Sources mobiles

		1965	1970	1975	1979	1980	1981	1982	1983
Canada	a)	49	156	32	..	158	..	..	..
USA/Etats Unis		500	600	500	900	900	300	800	900
Japan/Japon	b)	..	..	99	..	120	..	..	..
Belgium/Belgique	g)	..	..	..	..	12	..	12	12
Denmark/Danemark		4	5	6	..	8	..	16	..
Finland/Finlande	h)	7	9	10	10	10	..	..	10
France	i)	..	68	108	129	137	95	96	97
Germany/Allemagne	d)	99	115	122	126	114	..	102	..
Ireland/Irlande		..	..	4	5	5	..	..	5
Luxembourg	k)	..	..	..	..	1.5	..	..	0.7
Netherl./Pays Bas	e)	25	27	26	20	19	16	16	16
Norway/Norvège	j)	..	..	17	18	18	17	19	20
Portugal		..	7	7	14	16	..	..	..
Spain/Espagne		..	..	57	84	82	..	..	..
Sweden/Suède	c)	..	..	19	..	23	..	..	..
UK/Royaume Uni	f)	130	70	70	70	50	60	60	50

Power/Centrales d'énergie

		1965	1970	1975	1979	1980	1981	1982	1983
Canada	a)	262	435	528	..	745	..	..	..
USA/Etats Unis		10400	15800	16600	16000	15500	14700	14200	14000
Japan/Japon	b)	..	..	451	..	349	..	..	..
Belgium/Belgique	g)	..	..	..	..	794	..	664	548
Denmark/Danemark		85	276	187	..	214	..	203	..
Finland/Finlande	h)	60	100	100	115	125	..	..	250
France	i)	..	770	944	1266	1241	950	935	646
Germany/Allemagne	d)	1322	1652	1847	1873	1868	..	1863	..
Ireland/Irlande		..	..	82	109	98	..	..	44
Luxembourg	k)	..	..	..	..	..	..	..	..
Netherl./Pays Bas	e)	190	130	32	160	194	214	149	91
Norway/Norvège	j)	0.3	0.3	0.3	0.4	0.4	0.4	0.5	..
Portugal		6	18	57	67	99	..	..	..
Spain/Espagne		..	..	969	1577	..	..	..	..
Sweden/Suède	c)	..	..	66	..	35	..	..	..
UK/Royaume Uni	f)	2250	2770	2820	3100	2870	2710	2650	2330

Fuel Combustion/Utilisation de combustibles

		1965	1970	1975	1979	1980	1981	1982	1983
Canada	a)	1130	1003	397	..	826	..	..	..
USA/Etats Unis		550	5500	3700	3400	3300	3100	3100	2800
Japan/Japon	b)	..	..	..	..	..	..	..	..
Belgium/Belgique	g)	..	..	..	..	..	..	..	..
Denmark/Danemark		269	352	232	..	232	..	185	..
Finland/Finlande	h)	100	165	195	245	245	..	..	..
France	i)	..	1622	1695	1788	1661	1251	1170	1116
Germany/Allemagne	d)	1711	1774	1560	1303	1116	..	929	..
Ireland/Irlande		..	..	104	120	174	..	..	95
Luxembourg	k)	..	..	..	..	21	..	..	11
Netherl./Pays Bas	e)	700	530	275	236	170	160	155	
Norway/Norvège	j)	..	..	78	67	63	51	45	32
Portugal		40	78	90	130	122	..	..	..
Spain/Espagne		..	..	942	938	812	..	..	..
Sweden/Suède	c)	..	..	370	..	300	..	..	..
UK/Royaume Uni	f)	3630	3250	2240	2170	1750	1460	1330	1110

Industrial Process/Procédés industriels

		1965	1970	1975	1979	1980	1981	1982	1983
Canada	a)	5152	4940	4031	..	3040	..	..	..
USA/Etats Unis		6900	6200	4700	4200	3500	3700	3200	3100
Japan/Japon	b)	..	..	1109	..	720	..	..	..
Belgium/Belgique	g)	..	..	..	..	50	..	50	50
Denmark/Danemark		-	1	1	..	1	..	1	..
Finland/Finlande	h)	130	240	230	190	190	..	..	275
France	i)	..	505	466	432	427	337	339	286
Germany/Allemagne	d)	68	58	71	98	102	..	106	..
Ireland/Irlande		..	..	..	..	..	..	..	..
Luxembourg	k)	..	..	..	..	..	..	..	..
Netherl./Pays Bas	e)	..	..	..	59	60	50	60	60
Norway/Norvège	j)	..	..	58	59	60	59	52	49
Portugal		7	13	24	26	27	..	..	..
Spain/Espagne		..	..	961	1059	1054	..	..	..
Sweden/Suède	c)	..	..	230	..	150	..	..	98
UK/Royaume Uni	f)	..	..	..	..	..	..	..	..

Miscellaneous/Divers

		1965	1970	1975	1979	1980	1981	1982	1983
Canada	a)	-	6	3	..	5	..	..	..
USA/Etats Unis		300	100	-	-	-	-	-	-
Japan/Japon	b)	..	..	127	..	125	..	..	..
Belgium/Belgique	g)	..	..	..	..	..	..	..	..
Denmark/Danemark		..	..	..	..	..	..	..	..
Finland/Finlande	h)	..	..	..	..	..	..	..	..
France	i)	-	-	-	-	-	-	-	-
Germany/Allemagne	d)	..	..	..	..	..	..	..	..
Ireland/Irlande		..	..	..	..	..	..	..	..
Luxembourg	k)	..	..	..	..	..	..	..	..
Netherl./Pays Bas	e)	..	..	2.2	3.4	4.5	4.7	4.7	4.7
Norway/Norvège	j)	..	..	..	..	..	..	..	..
Portugal		..	..	..	..	..	..	..	..
Spain/Espagne		..	..	74	97	..	..	..	..
Sweden/Suède	c)	..	..	1	..	2	..	..	3
UK/Royaume Uni	f)	..	..	..	..	..	..	..	..

Total

		1965	1970	1975	1979	1980	1981	1982	1983
Canada	a)	6593	6540	5607	..	4774	..	..	..
USA/Etats Unis		23600	28200	25600	24500	23200	22300	21300	20800
Japan/Japon	b)	..	..	1780	..	1314	..	..	..
Belgium/Belgique	g)	..	..	..	..	856	..	726	610
Denmark/Danemark		358	574	426	..	455	..	405	..
Finland/Finlande	h)	400	515	535	560	570	..	..	475
France	i)	..	2966	3275	3615	3460	2633	2940	2785
Germany/Allemagne	d)	3200	3600	3600	3400	3200	..	3000	..
Ireland/Irlande		..	..	190	234	277	189	155	140
Luxembourg	k)	..	..	..	..	23	..	..	12
Netherl./Pays Bas	e)	..	..	..	440	450	455	385	305
Norway/Norvège	j)	..	..	147	144	141	127	116	107
Portugal		..	176	178	237	264	..	..	..
Spain/Espagne		..	..	3004	3756	..	..	..	..
Sweden/Suède	c)	..	930	690	..	510	..	..	302
UK/Royaume Uni	f)	6070	6090	5130	5340	4670	4230	4040	3690

NOTES:

a) 1975 data refer to 1974.
b) 'Power' refers to plants owned and operated by power generating companies: 'fuel combustion' is subsumed in 'power' and 'industrial process' categories; 'miscellaneous' includes commercial. residential as well as waste incineration. 1975 data refer to 1977.
c) Total figures are rounded because of uncertainty.
d) 1965 and 1975 data refer to 1966 and 1974. 1980 data are arithmetic averages based on 1978 and 1982 data.
e) 'Miscellaneous' refers to combustion of solid waste disposal: 'Industrial process' data are upper level estimates ranging between 40 000 and 65 000 tonnes. Data for 'industrial process', 'miscellaneous' and 'total' are estimated as well as all 1983 data.
f) 'Mobile sources' data neither include aviation fuel nor marine fuel: 'industrial process' data can be estimated less than 10% of total from 'fuel combustion'.
g) 1980 1982 and 1983 data for power include fuel combustion.
h) 1983 data for power include fuel combustion.
i) 1970 data refer to 1971.
j) 1975 data refer to 1976 except for 'power'.
k) 'Fuel combustion' includes 'industrial process'.

NOTES:

a) Les données 1975 sont de 1974.
b) 'Les centrales d'énergie' font référence aux centrales appartenant à des compagnies de production d'énergie et gérées par elles: 'L'utilisation de combustibles' est répartie entre 'centrales d'énergie' et 'procédés industriels'; 'divers' inclut les secteurs commercial. résidentiel et l'incinération des déchets. Les données 1975 sont de 1977.
c) Les totaux sont arrondis afin de tenir compte des incertitudes.
d) Les données 1970. 1975 et 1979 sont de 1966. 1974 et 1978. Les données 1980 sont des moyennes arithmétiques des données 1978 et 1982.
e) 'Divers' fait référence à l'incinération des déchets: les données relatives aux 'procédés industriels' sont des valeurs supérieures estimées variant de 40 000 à 65 000 tonnes. Les données relatives aux 'procédés industriels', 'divers' et total. de même que les données 1983 sont des estimations.
f) Les données 'sources mobiles' n'incluent ni le carburant avion ni le avion ni le carburant bâteaux les données 'procédés industriels' peuvent être estimées à moins de 10% du total de la catégorie 'utilisation de carburant'.
g) Les données 1980 1982 et 1983 pour les centrales d'énergie incluent l'utilisation de combustibles'.
h) Les données 1983 pour les centrales d'énergie incluent les données sur l'utilisation de combustibles.
i) Les données 1970 sont de 1971.
j) Les données 1975 sont de 1976 excepté pour les centrales d'énergie.
k) 'Utilisation de combustibles' inclut 'procédés industriels'.

SOURCE: OECD Compendium 1985 (3)

EMISSIONS OF NOx, by source, selected countries, 1965-1983

EMISSIONS DE NOx, par source, pays sélectionnés, 1965-1983

1000 tonnes

Mobile Sources/Sources mobiles

		1965	1970	1975	1979	1980	1981	1982	1983
Canada	a)	512	760	1206	..	1114	..	..	..
USA/Etats Unis		5600	7600	8900	9600	9200	9300	8900	8800
Japan/Japon	b)	..	..	666	..	567	..	..	..
Belgium/Belgique	h)	..	..	-	..	120	..	120	120
Denmark/Danemark		46	59	63	..	63	..	82	..
France	c)	..	537	879	1031	1042	1067	1073	1085
Germany/Allemagne	d)	800	1008	1188	1580	1637	..	1692	..
Ireland/Irlande		..	..	16	21	20	..	..	..
Netherl./Pays Bas	e)	190	270	250	275	280	275	275	270
Norway/Norvège		..	..	..	107	100	99	103	105
Portugal		..	55	78	188	208	..	..	..
Spain/Espagne		..	..	357	510	501	..	..	..
Sweden/Suède	f)	..	162	195	..	199	..	..	202
UK/Royaume Uni	g)	..	..	473	532	533	514	526	546

Power/Centrales d'énergie

		1965	1970	1975	1979	1980	1981	1982	1983
Canada	a)	57	160	197	..	245	..	..	..
USA/Etats Unis		3200	4500	5200	6200	6400	6500	6200	6300
Japan/Japon	b)	..	..	312	..	238	..	..	..
Belgium/Belgique	h)	..	..	..	..	177	..	157	131
Denmark/Danemark		..	..	52	..	99	..	116	..
France	c)	..	209	228	326	297	240	249	200
Germany/Allemagne	d)	472	636	870	862	860	..	859	..
Ireland/Irlande		..	..	25	30	28	..	..	..
Netherl./Pays Bas	e)	72	66	59	78	82	85	80	77
Norway/Norvège		..	..	..	0.5	0.5	..	..	..
Portugal		2	4	17	13	19	..	..	..
Spain/Espagne		..	..	84	100	..	..	..	..
Sweden/Suède	f)	..	..	18	..	..	..	..	..
UK/Royaume Uni	g)	..	..	766	876	851	819	767	763

Fuel Combustion/Utilisation de combustibles

		1965	1970	1975	1979	1980	1981	1982	1983
Canada	a)	247	231	362	..	395	..	..	..
USA/Etats Unis		4700	4600	4100	4300	3700	3700	3700	3400
Japan/Japon	b)	..	..	..	..	..	..	..	..
Belgium/Belgique	h)	..	..	..	..	..	..	..	..
Denmark/Danemark		..	..	88	..	79	..	52	..
France	c)	..	547	481	410	482	436	397	377
Germany/Allemagne	d)	690	716 -	676	834	583	..	531	..
Ireland/Irlande		..	..	17	18	18	..	..	..
Netherl./Pays Bas	e)	108	134	116	125	112	109	107	96
Norway/Norvège		..	..	..	12	13	11	11	..
Portugal		8	12	14	19	19	..	..	..
Spain/Espagne		..	..	105	104	90	..	..	..
Sweden/Suède	f)	..	..	72	..	..	..	..	..
UK/Royaume Uni	g)	..	..	519	522	428	410	397	387

Industrial Process/Procédés industriels

		1965	1970	1975	1979	1980	1981	1982	1983
Canada	a)	11	14	47	..	51	..	..	..
USA/Etats Unis		600	700	700	700	700	700	600	600
Japan/Japon	b)	..	..	615	..	540	..	..	..
Belgium/Belgique	h)	..	..	..	..	20	..	20	20
Denmark/Danemark		..	..	..	..	..	..	..	..
France	c)	..	29	26	30	28	25	20	..
Germany/Allemagne	d)	38	40	26	23	21	..	18	..
Ireland/Irlande		..	..	..	..	..	..	..	..
Netherl./Pays Bas	e)	..	..	..	52	30	30	30	30
Norway/Norvège		..	..	..	15	12	10	9	9
Portugal		0.6	0.6	0.6	0.6	0.7	..	..	..
Spain/Espagne		..	..	67	81	87	..	..	..
Sweden/Suède	f)	..	..	22	..	24	..	..	15
UK/Royaume Uni	g)	..	..	..	..	..	..	..	..

Miscellaneous/Divers

		1965	1970	1975	1979	1980	1981	1982	1983
Canada	a)	23	68	77	..	27	..	..	..
USA/Etats Unis		600	700	200	300	300	300	200	300
Japan/Japon	b)	..	..	84	..	90	..	..	..
Belgium/Belgique	h)	..	..	..	..	..	..	..	..
Denmark/Danemark		..	..	..	..	..	..	..	..
France	c)	-	-	-	-	-	-	-	-
Germany/Allemagne	d)	..	..	..	..	..	..	..	..
Ireland/Irlande		..	..	..	..	..	..	..	..
Netherl./Pays Bas	e)	..	..	1.7	3	13	13	13	13
Norway/Norvège		..	..	..	..	..	..	..	..
Portugal		..	..	..	..	..	..	..	..
Spain/Espagne		..	..	12	16	..	..	..	..
Sweden/Suède	f)	..	..	1	..	..	..	..	..
UK/Royaume Uni	g)	..	..	7	8	8	..	..	..

Total

		1965	1970	1975	1979	1980	1981	1982	1983
Canada	a)	850	1233	1889	..	1832	..	..	..
USA/Etats Unis		14700	18100	19100	21100	20300	20500	19600	19400
Japan/Japon	b)	..	..	1677	..	1435	..	..	..
Belgium/Belgique	h)	..	..	..	..	317	..	297	271
Denmark/Danemark		..	..	203	..	241	..	250	..
France	c)	..	1322	1612	1893	1847	1766	1739	1674
Germany/Allemagne	d)	2000	2400	2700	3100	3100	..	3100	..
Ireland/Irlande		..	..	58	69	66	62	59	57
Netherl./Pays Bas	e)	..	..	457	533	525	522	515	496
Norway/Norvège		..	..	..	134	125	120	122	124
Portugal		..	72	104	221	247	..	..	..
Spain/Espagne		..	..	624	811	..	..	..	..
Sweden/Suède	f)	..	302	310	..	317	..	..	290
UK/Royaume Uni	g)	..	..	1758	1930	1812	1743	1690	1696

NOTES:

a) 1975 data refer to 1974.

b) 'Power' refers to plants owned and operated by power generating companies: 'fuel combustion' is subsumed in 'power' and 'industrial process' categories: 'miscellaneous' includes commercial, residential as well as waste incineration. 1975 data refer to 1977.

c) 1970 data refer to 1971.

d) 1965 1975 and 1979 data refer to 1966 1974 and 1978. 1980 data are arithmetic averages based on 1978 and 1982 data.

e) 'Miscellaneous' refers to natural sources as well as combustion of solid waste disposal: 'industrial process' figures are upper level estimates ranging between 20 000 and 52 000 tonnes. Data for 'industrial process'. 'miscellaneous' and 'total' are estimated. 1983 data are estimates.

f) Total figures are rounded because of uncertainty.

g) 'Mobile source' neither include aviation fuel nor marine fuel: 'miscellaneous' refer to incineration and agricultural burning.

h) 1980 1982 and 1983 data for power include fuel combustion.

NOTES:

a) Les données 1975 sont de 1974.

b) Les centrales d'énergie font référence à celles appartenant à des compagnies de production d'énergie et gérées par elles: l'utilisation de combustibles est répartie entre 'centrales d'énergie' et 'procédés industriels': 'divers' inclut les secteurs commercial, résidentiel et l'incinération des déchets. Les données 1975 sont de 1977.

c) Les données 1970 sont de 1971.

d) Les données 1970 1975 et 1979 sont de 1966 1974 et 1978. Les données 1980 sont des moyennes arithmétiques des données 1978 et 1982.

e) 'Divers' fait référence aux sources naturelles aussi qu'à l'élimination des déchets solides par combustion: les données relatives aux 'procédés industriels' sont des limites supérieures estimées variant de 20 000 à 50 000 tonnes. Les données pour 'procédés industriels'. 'divers' et 'total' de même que les données 1983 sont des estimations.

f) Les totaux sont arrondis afin de prendre en compte les incertitudes.

g) Les données 'sources mobiles' n'incluent ni le carburant avion. ni le carburant bateau: les données 'divers' font référence à l'incinération des déchets et aux brûlis en agriculture.

h) Les données 1980 1982 et 1983 pour les centrales d'énergie incluent l'utilisation des combustibles.

SOURCE: OECD Compendium 1985 (3)

SULPHUR EMISSIONS AND DEPOSITION : EUROPE

MEAN ANNUAL DEPOSITION FOR THE PERIOD 78 10 1 12 TO 82 10 1 6
TOTAL (DRY+WET) DEPOSITION OF SULPHUR
HORISONTAL - EMITTERS
VERTICAL - RECEIVERS
UNIT - 1000.TONNES SULPHUR PER YEAR

Emitter countries ⟶

Receiver countries ⟶

	AL	A	B	BG	CS	DK	SF	F	DDR	D	GR	H	IS	IRL	I	L	NL	N	PL	P	R	E	S	CH	TR	SU	UK	YU	RE	IND	SUM
AL	12	0	0	3	2	0	0	3	2	1	3	3	0	0	12	0	0	0	1	0	1	1	0	0	0	0	1	19	1	14	85
A	0	62	3	0	46	0	0	26	31	40	0	16	0	0	72	1	2	0	17	0	1	4	0	4	0	2	11	42	0	36	422
B	0	0	84	0	2	0	0	34	3	29	0	0	0	0	1	1	6	0	1	0	0	1	0	0	0	0	21	0	0	12	198
BG	2	1	0	159	11	0	0	3	9	6	9	17	0	0	12	0	0	0	10	0	23	2	0	0	5	13	2	57	1	35	413
CS	0	15	5	1	440	1	0	24	131	59	0	61	0	0	24	1	4	0	88	0	5	2	0	2	0	7	14	43	0	37	969
DK	0	0	2	0	4	47	0	5	14	14	0	1	0	0	1	0	2	0	6	0	0	0	2	0	0	1	15	1	0	14	132
SF	0	0	3	1	10	5	92	7	25	20	0	4	0	0	2	0	3	2	22	0	1	0	17	0	0	53	20	4	0	66	363
F	0	2	41	0	15	1	0	760	33	124	0	2	0	3	40	6	17	0	9	3	0	94	1	9	0	1	122	6	2	205	1505
DDR	0	2	10	0	64	4	0	25	586	103	0	5	0	0	5	1	0	0	29	0	1	1	1	1	0	3	20	7	0	30	910
D	0	9	45	0	68	6	0	136	149	660	0	7	0	1	31	6	27	0	24	0	1	9	1	0	0	3	88	15	0	96	1380
GR	4	1	0	39	5	0	0	4	5	5	111	7	0	0	20	0	0	0	4	0	5	3	0	0	5	5	2	37	2	36	305
H	0	11	1	3	56	0	0	9	25	17	0	227	0	0	36	0	1	0	29	0	11	1	0	0	0	5	5	93	0	24	560
IS	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	20	26
IRL	0	0	0	0	6	0	0	2	1	2	0	0	0	22	0	0	0	0	0	0	0	1	0	0	0	0	15	0	0	32	80
I	0	0	3	2	17	0	0	68	17	29	1	14	0	0	940	1	2	0	11	0	2	22	0	0	0	2	13	73	6	103	1355
L	0	0	1	0	0	0	0	4	0	2	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	1	0	0	1	14
NL	0	0	21	0	3	0	0	19	7	51	0	0	0	0	1	0	53	0	1	0	0	1	0	0	0	0	33	1	0	14	210
N	0	0	5	0	9	9	2	15	26	25	0	2	0	1	2	0	5	24	14	0	0	2	11	0	0	9	53	3	0	92	314
PL	0	9	11	3	108	10	1	36	270	106	1	40	0	1	26	2	10	0	776	0	0	3	5	1	1	36	41	45	0	90	1712
P	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	25	0	16	0	0	0	0	1	0	0	30	80
R	1	5	2	35	49	1	0	11	35	23	5	91	0	0	34	1	2	0	54	0	192	2	1	1	4	53	8	143	1	70	627
E	0	0	3	0	2	0	0	44	6	22	0	0	0	0	4	1	3	0	1	11	0	429	0	1	0	0	17	1	3	113	666
S	0	1	7	1	22	23	12	19	53	45	0	6	0	1	7	1	7	10	41	0	2	2	100	0	0	27	51	0	0	138	587
CH	0	1	2	0	4	0	0	29	6	19	0	1	0	0	45	0	1	0	2	0	3	4	0	16	0	0	7	3	0	21	165
TR	1	1	0	37	0	0	0	5	9	6	25	10	0	0	16	0	1	0	9	0	0	4	0	0	209	23	2	30	2	93	505
SU	4	17	23	80	221	30	60	82	342	233	27	155	0	3	100	5	29	6	538	0	139	11	45	4	534	273	126	232	3	1090	7972
UK	0	0	9	0	5	1	0	35	12	26	0	1	0	0	1	1	7	0	4	0	0	5	0	0	0	1	790	1	0	87	996
YJ	4	19	3	39	52	1	0	32	35	30	6	86	0	0	193	1	3	0	30	0	17	10	0	2	1	10	13	678	3	106	1377
	AL	A	B	BG	CS	DK	SF	F	DDR	D	GR	H	IS	IRL	I	L	NL	N	PL	P	R	E	S	CH	TR	SU	UK	YU	RE	IND	SUM

Table 1: Calculated European sulphur budget for a 4-year period starting 1 October 1978. Unit: 10^3 tonnes of sulphur per annum. Assumed emissions are given in Table 2. Depositions from emitter countries are given in vertical columns, depositions to receiver countries in horizontal rows. IND signifies indeterminate wet depositions. Total estimated deposition is given as SUM in the right-hand column.

Country	Area ($10^3 km^2$)	Q1	Q2 (10^3 tonnes S)
Albania	28,7	50	
Austria	83,9	215	
Belgium	30,5	380	405
Bulgaria	110,9	500	
Czechoslovakia	127,9	1500	
Denmark	43,1	228	
Finland	337,1	270	
France	544,0	1800	
German Democratic Rep.	108,2	2000	
Germany, Federal Rep.of	249,6	1815	
Greece	132,0	350	
Hungary	93,0	750	
Iceland	60,7	6	
Ireland	68,9	88	
Italy	301,2	2200	
Luxembourg	2,6	21	
Netherlands	41,0	240	
Norway	323,9	76	
Poland	312,7	1500	2150
Portugal	76,7	84	
Romania	237,5	1000	100
Spain	500,0	1000	
Sweden	450,0	275	
Switzerland	41,3	58	
Turkey	460,8	500	
USSR (within grid)	3363,4	8100	
United Kingdom	244,0	2560	
Yugoslavia	255,8	1475	

Table 2: Assumed national annual sulphur emissions, Q1. Unit: 10^3 tonnes S. The data are taken from the EMEP emission inventory, which gave estimates for 1978. In three cases, official corrections were received during the model calculations. These were effected from 1 April 1980 and are given under Q2. Information received after completion of the calculations show that the emissions in some other countries have undergone significant changes during the period of calculation (1978-1982) In such cases, the calculated depositions from the countries can be proportionally adjusted.

3. <u>Calculated sulphur deposition and concentration patterns from all European emissions</u>.

The following patterns are shown:

a) Mean annual dry deposition

b) Mean annual wet deposition

c) Mean annual "indeterminate" background wet deposition

d) Mean annual total deposition, i.e. the sum of a), b) and c)

e) Mean annual dry deposition in % of total deposition

f) Mean annual wet deposition in % of total deposition

g) Mean annual "indeterminate" wet deposition in % of total deposition

h) Mean concentration of sulphur dioxide

i) Mean concentration of particulate sulphate

j) Precipitation-weighted mean concentration of sulphate in precipitation

The isoline of a), b), c) and d) are 250, 500, 1000, 2000, 4000 and 8000 mg/m^2 annually in S-units. Maxima are shown with numbers.

The isolines of e), f) and g) are 15, 30, 45, 60 and 75%. Maxima are shown as numbers.

The isolines of h) and i) are 0.25, 0.5, 1, 2, 4, 8 and 16 in $\mu g/m^3$ as S.

The isolines of j) are 0.5, 1.0, 1.5, 2.0 and 2.5 in mg/l as S.

ANNEX 2

EXTRACTS FROM SOME OECD RECOMMENDATIONS

EXTRACT FROM OECD RECOMMENDATION ON ENVIRONMENTALLY FAVOURABLE ENERGY OPTIONS AND THEIR IMPLEMENTATION

ELEMENTS OF ENVIRONMENTALLY FAVOURABLE ENERGY OPTIONS

The following elements are indicative of the types of action which could be undertaken by Member countries, depending on their specific circumstances, in order to implement this Recommendation:

a) Enhanced institutional linking.

i) Co-operation between those responsible for energy planning, including long-term supply and demand forecasting, and those responsible for assessing environmental impacts;

ii) Establishment of environmental policy "early warning systems" that would alert energy policymakers to issues that are at an early stage of identification and understanding, but that might arouse serious concern in a few years time when these issues are better understood;

iii) Development of joint promotional initiatives by energy and environmental agencies to increase public acceptance of measures that further energy and environment objectives, e.g. improving building heating and cooling efficiencies;

iv) Closer co-operation in government sponsored R&D on environmental control technologies, environmentally favourable conversion technologies and system impact assessment techniques;

v) Closer consultations between government departments responsible for both energy and environment, and industry involved in energy investments and pollution control equipment manufacturing.

b) Better analytical and data capabilities

i) Improved energy/environment data bases, including energy efficiency and environmental impact indicators;

ii) Guidelines and techniques to increase the reliability and comparability of estimates of environmental costs and benefits related to energy;

iii) Development of better techniques to compare differing environmental risks of energy technologies;

iv) Co-operation among concerned agencies towards a better understanding of the relationships linking economic growth, energy systems and the environment.

c) Promotion of more efficient use of energy from the environmental perspective

i) Encouragement for energy policies designed to achieve investment by industry and individual consumers in more energy-efficient buildings, vehicles and other equipment, and better energy management;

ii) Identification and quantification of environmental benefits from improved efficiency of energy use;

iii) Better information to consumers on these environmental benefits;

iv) Encouragement of co-operation between energy and environmental institutions to identify energy initiatives offering simultaneous high environmental gains and energy savings, and to attempt to quantify the benefits to both energy and environment.

d) Reduction of barriers to environmentally favourable energy options

i) Co-operation between governments to reduce technological and economic barriers, and help to develop, improve and bring onstream new environmentally favourable energy technologies;

ii) Improved transparency relating to the cost of energy-using equipment (e.g. specification of running costs) and environmental performance (e.g. specific pollutant emissions) to enable consumers to make informed and environmentally sensitive decisions;

iii) Identification and reduction of institutional barriers;

iv) Improvement of public awareness concerning environmentally favourable energy options, and of ability to apply these options in their use of energy, taking into account both energy and environmental benefits.

e) Integration of environmental costs in energy pricing and incentives

i) Identification of energy pricing policies or practices which are not in accordance with the Polluter Pays Principle;

ii) Incentives (e.g. tax credits, grants), where appropriate, to undertake environmentally favourable energy investments, which reflect not only energy savings but also environmental benefits.

f) Improved regulations

i) Sufficient flexibility in regulatory schemes to encourage research and innovation of environmentally favourable and economically efficient energy options;

ii) Better integration of regulatory procedures at national, regional and local levels;

iii) Advance notice of changes in environmental regulations as far as possible, and adequate lead-time to comply with regulations;

iv) Consultations at an early stage among concerned parties regarding environmental problems which may require future regulatory changes.

OVERVIEW OF ENVIRONMENTALLY FAVOURABLE ENERGY TECHNOLOGIES

eneric Technology / conomic Sector(s) for Application	Environmental Gain / Energy Savings Potential	Timescale for Significant Commercial Applications	International Variations	Impediments to Commercial Applications	Principal Policy Options
Combined Heat & Power (CHP) and District Heating - Industry - Power Generation - Residential/ commercial	Reduced dispersed emissions and reduced power generation emissions Primary energy for electricity generation, oil for domestic heating .	Economic now in some situations	Viability depends on (a) Lack of competition from natural gas, and (b) favourable political and admin. structures	Surpluses and shortages tend to coincide with those on electricity grids. Obtaining a 'fair price' from electric utilities. Availability of sites and connections with grid	Reserve existing power station sites in favourable locations for potential future CHP use. Ensure utilities don't discriminate through unfair pricing for buying and selling. Assistance for demonstration schemes. Low interest loans.
Heat Pumps - Industry - Residential/ Commercial	Reduced emissions from direct fossil fuel burning and from power generation Oil and electricity saving but attractive only in certain countries and regions	Technology available today. 10-15 yrs where competitive with alternative fuels	Most competitive where - requirements for heating and cooling - Air is space-heating medium - Gas and DH not available	High initial cost Alternative heating fuels	Provision of subsidy for heat pump investment. Support for heat pump R & D, especially to reduce capital cost
Improved Internal Combustion Engines and Automotive Design - Transportation	Reduced emissions from IC engines Significant oil-savings	10-15 years, allowing for introduction of new designs and rotation of car stock	USA, Japan, France Germany, Italy, UK and Sweden the main OECD automobile manufacturers	Car industry highly competitive. Main impediments would be if petrol prices fell sharply and were expected to stay low in medium term	Government standards for higher miles per gallon (probably combined with environmental standards); direct intervention to stimulate search for radically new automobile designs
Electric Battery Vehicles - Transportation	Reduced emissions from IC engines in urban areas, emissions from electricity generation more controllable Entirely oil-savings	Economic now for some delivery vehicles. 15-25 yrs for light vans and shorter distance car journey	Ditto	Efficiency of battery which limits payload distance between charges. High costs per vehicle due to small market. Increasing efficiency of petrol and diesel vehicles	Continuing effort to improve battery efficiency. Public sector procurement for organisations with large fleets of light vans

OVERVIEW OF ENVIRONMENTALLY FAVOURABLE ENERGY TECHNOLOGIES (continued)

Generic Technology Economic Sector(s) for Application	Environmental Gain Energy Savings Potential	Timescale for Significant Commercial Applications	International Variations	Impediments to Commercial Applications	Principal Policy Options
5. Process Heat Recovery - Industry - Commercial	Reduced emissions from direct fossil fuel use Oil, gas and coal in industry	Waste heat recovery often economic now	Applicable especially where concentration of heavy industries	Often difficult to sell recovered waste heat (matching loads required close by) Lack of consumer awareness and cashflow constraint	Information and advisory services. Assistance for demonstration schemes. Low interest loans
6. Electronic Controls - Industry - Transportation - Residential/ Commercial - Agriculture	Reduced emissions from all direct fuel use and power generation Large, all sectors; all types of fuel. May improve competitiveness of electricity	Economic now	Smaller and less advanced OECD countries lack strong electronics industries	Lack of consumer awareness and cashflow constraints on investment	Information and advisory services. Assistance for demonstration schemes. Low interest loans
7. Water Heating - Industry - Commercial	Reduced emissions from direct fossil fuel use Oil, gas and coal mainly in industrial and commercial boilers	Improved boiler designs and controls currently economic		Slow rotation of capital stock, but improved controls and insulation etc. can be fitted to existing boilers and systems	Information and Advisory services. Assistance for demonstration schemes. Low interest loans
8. Urban waste for power generation and/or DH - Residential/ Commercial - Power generation	Avoided emissions and fuel cycle pollution from oil/ coal -- Reduced waste disposal Local and minor, except in large conurbations	Economic now in some situations		Organisation of refuse collection and of electricity supply industry	Reserve existing power station sites in favourable locations for potential future CHP use. Ensure utilities don't discriminate through unfair pricing for buying and selling. Assistance for demonstration schemes. Low interest loans

SOURCE: Adapted from IEA Energy Technology Policy Study, 1984.

EXTRACT FROM OECD RECOMMENDATION ON CONTROL OF AIR POLLUTION FROM FOSSIL FUEL COMBUSTION

GUIDING PRINCIPLES

1. General

a) Introduction of relatively inexpensive measures to reduce these pollutants, for example, use of lower sulphur fuels, more coal cleaning, desulphurisation and blending of some fuel oils, or boiler design modifications to reduce nitrogen oxide formation.

b) Development of innovative regulatory schemes that can improve efficiency or flexibility of compliance while achieving regulatory goals.

c) Better enforcement of compliance with existing emission control regulations for both stationary sources and vehicles.

d) Increased efficiency of energy production and use, such as application of waste heat from electricity generation and steam production to industrial or residential/commercial use, improved building insulation, use of heat pumps, more efficient vehicle engines and design, better industrial processes, and other means.

e) Increased use of district heating systems with adequate pollution control or other less polluting energy systems, in urban areas where they are practicable and economically feasible, and can replace dispersed fossil fuel heating installations.

f) Regulations to ensure availability and use of clean fuels for combustion installations or against use of polluting fuels where emission controls are not usually economically feasible (e.g. small central heating boilers).

2. Pollution Control Technologies

a) Encouragement and incentives for research and development of efficient advanced technologies for pollution control before and during fossil fuel combustion and for control of pollutant emissions after combustion.

b) Encouragement and incentives for the development of new cost-effective fossil fuel combustion technologies and for the improvement of existing technologies, to achieve a more effective reduction of air pollutant emissions.

c) Support for the commercialisation and market penetration of new combustion technologies which are environmentally less polluting than existing ones.

d) Encouragement and incentives for the development and application of improved coal beneficiation and fuel oil refining technologies.

3. Large Stationary Installations

a) Implementation of emission standards by an effective programme of control measures for large stationary installations, consistent with the use of the best available and economically feasible technologies, and with the target, through national policies and programmes, of achieving the reduction of total national emissions required to reach environmentally acceptable air quality and deposition levels, and where appropriate with a transitional regime for existing plants.

b. Encouragement or incentives (e.g. tax, investment, loan or grant) for timely retirement or modernisation of older, more polluting installations, to the extent that this does not conflict with other economic policies.

4. Mobile Sources

a) Implementation as soon as practicable of internationally harmonised emission standards by category for major air pollutants from vehicles, implying for many countries substantive reduction of pollutant emissions by using the best available and economically feasible technology.

b) Encouragement and incentives for the development of less polluting and more efficient engines and vehicles.

c) Promotion of good vehicle maintenance.

d) Encouragement and incentives for the use of less polluting fuels for transportation (for example, liquified petroleum gas and compressed natural gas), where technologically and economically feasible.

e) Regulations or other incentives to ensure the availability and use of unleaded gasoline as soon as possible and to phase out leaded gasoline as a long-term goal.

f) Encouragement and incentives for the use of public transportation where appropriate.

g) Setting and enforcement of speed limits for driving, especially on highways.

h) Traffic management in urban areas.

5. Information Needs

a) Improvement of the air pollutant emissions data base by adopting comparable techniques and methods of measuring emissions, and providing reliable emissions inventories.

b) Continuous monitoring of air pollutant emissions.

c) Continuing international research coordination and exchange of information.

d) Encouragement for the transfer between countries of available technologies and methods to reduce air pollution.

e) International cooperation on research and development to increase the effectiveness and to reduce the costs of controlling emissions, particularly for retrofitting existing installations.

6. Monitoring

Monitoring and reporting of the application and effectiveness of these guiding principles on a national basis.

ANNEX 3

WHAT RECENT REPORTS SAY ABOUT ACID RAIN

Over the past several years a number of studies have been carried out mainly in Europe and North America on the general topic of acid deposition. This Annex provides some quotes from selected studies regarding the present state of knowledge of mechanisms and effects, as support for the summary of the facts as presented in Section VII. The studies are cited in the References to the paper.

1. ACID DEPOSITION IN THE PAST

"Measurements of acidity in preserved snow indicate that contemporary levels of acid deposition did not occur before the Industrial Revolution......precipitation in previous ages has (1) generally been even less acidic than the current background average in remote areas and (2) only about matched this current background for 1 or 2 years at a time, after a few volcanic eruptions." (GAO 1984) (6)

"Historical lake acidity data, measured in lake sediments, show that certain North American and European lakes, which had stabilized at near-neutral pHs capable of suppoorting fish at some time after the glaciers receded thousands of years ago, have been rapidly acidified in recent decades.......starting about in the late 1950's, steep drops ocurred in the Swedish lake pHs, from values at or above pH 6 to levels as low as about pH 4." (GAO 1984) (6)

2. THE ORIGINS OF ACID DEPOSITION

"The main acidifying atmospheric pollutants arising from man's activities are sulphur dioxide (SO2) and nitrogen oxides (NOX). Averaged over the surface of the globe, man-made and natural emissions of SO2 and its precursors are of comparable magnitude (in the order of 100 million tonnes of sulphur per year). The bulk of man-made emissions occurs over industrialised regions covering less than 5 percent of the earth's surface: Europe, Eastern North

America, China-Japan. Within these regions, man-made sulphur emissions exceed the natural emissions by a factor of five to twenty." (Stockholm Conference 1982) (15).

"At most, 5 percent of the deposited sulphur is currently thought to come from natural sulphur sources. Natural nitrogen sources in North America are considered to be from 4-40 percent of the total emissions" (NAPAP 1983) (19)

"Human activities thus contribute about 75 percent of total sulfur emissions in the West [of the USA] - somewhat less than in the East, where anthropogenic emissions equal 90-95 percent of the total" (WRI 1985) (24)

"In general, industrial sources, including utilities, account for most of the SO2 and particulates and about half the NOX. The utility contribution to total sulphur emissions in the Eastern United States varies from about 55 percent in winter to about 65 percent in the summer. Utilities and highway vehicles contribute most of the NOX, and industrial and transportation sources most of the hydrocarbons." (EPRI 1983) (17)

"Smelters, the largest single source of SO2 emissions in the West [of the USA], account for about half of all SO2 emissions." (WRI 1985) (24)

"Data for United Kingdom emissions of sulphur dioxide from 1850 and oxides of nitrogen from 1900 have been presented. Both have increased considerably during the twentieth century. Sulphur dioxide emissions reached a maximum in the mid-sixties and thereafter decreased sharply. Total NOX emissions, which are more uncertain, continued to rise until 1980." (Warren Spring 1983) (18)

3. THE MECHANISMS OF TRANSPORT AND DEPOSITION

"Scientists working on acid deposition agree that sulfur and nitrogen oxides are not accumulating in the atmosphere. Rather, all emitted oxides are deposited after a short stay or 'residence time' in the atmosphere, usually estimated as averaging several days." (GAO 1984) (6)

"Emitted SO_2 can be found free in the air, dissolved in cloud water, or deposited back on earth, in each case either as SO_2 or transformed to sulfate. It can take any one of four possible pathways to final deposition. Of these four, two are dominant in eastern North America --sulfate in precipitation and dry deposition of SO_2 gas. The other two -- SO_2 in precipitation and dry deposition of small sulfate particles -- make much smaller contributions to total deposition." (GAO 1984) (6)

"Dry deposition by any source will, on the average, be greater than its contribution to wet deposition near the source, and then become equal or less beyond about 200 miles." (GAO 1984) (6)

"Following along prevailing wind directions, major contributions can be deposited at distances out to the range of 200-500 miles, as shown by the displacement distances in North America and the cases of transport to Norway and Nova Scotia. By the time distances of 500 to 700 miles are reached, contributions to wet deposition begin to drop off substantially" (GAO 1984) (6)

"...wind-trajectory studies indicate that poolluted air from southern California can travel 500 kilometers or more northeast into northwestern Arizona. (WRI 1985) (24)

"The ratio of dry to wet deposition of acids in the Los Angeles basin might approach 15:1, a value far greater than the 1:1 ratio thought to typify the eastern United States." (WRI 1985) (24)

"Recent work indicates extremely high deposition from clouds onto forested mountain areas they rest upon." (GAO 1984) (6)

"Highly acidic fogs, with pH below two, have been observed in the Los Angeles basin." (WRI 1985) (24)

4. THE ROLES OF SULPHUR AND NITROGEN IN ACIDIFICATION

"Comparison of a large number of samples distributed in space and time, however, permits statistical correlations to be made, from which it may be inferred that the most likely annual average contributions to acidity in Northern Britain are 70 percent from sulphuric acid and 30 percent from nitric acid." (Warren Spring 1983) (18).

concentrations in air and rain during a period of increasing NOX emissions." (Warren Spring 1983) (18)

"Sulphates contribute about two-thirds of the acidity to precipitation in the north-eastern United States; but, nitrates can contribute over half of the acidity in the western regions." (NAPAP 1983) (19)

"The ratio of nitric to sulphuric acid in western [USA] precipitation is generally higher than it is in eastern precipitation." (WAI 1985) (24)

"Emitted NOX is extensively involved in complex atmospheric chemical reactions which also include reactive hydrocarbon pollutants, and these give rise to ozone and a number of other oxidants in addition to nitric acid itself. These processes make an accounting of the pathways and fates of emitted NOX a more complex matter than is the case for SO2." (GAO 1984) (6)

"...comparisons between geographical patterns of wet nitrate and sulfate deposition have led to some agreement that NOX and its oxidation products do not travel as far as the sulfur compounds." (GAO 1984) (6)

"Analysis of the data from the midwestern and northeastern United States indicates that the percentage of emitted SO2 that is deposited as sulphate in precipitation is approximately equal to the percentage of emitted NOX deposited as wet nitrate in that region." (NAS 1983)

5. THE LINEARITY OF THE EMISSION-DEPOSITION RELATIONSHIP

"...if a general decrease in emissions were to take place within a large industrialised region (about a thousand km), specific areas within this region might experience significantly smaller or larger decreases in deposition. However, the total deposition over the whole industrialised region would decrease approximately in proportion to the reduction in emission." (Stockholm Conference 1982) (15)

"...it is now suggested that, when averaged over the entire eastern half of North America, there appears to be nearly a linear relationship between sulphur oxide emissions and sulphate deposition. This relationship does not necessarily hold true for smaller spatial scales or shorter time frames." (NAPAP 1983) (19)

"Scientific work released in 1983 has now confirmed that, for eastern North America as a whole, acid sulfur deposition will change in essentially 1:1 proportion to changes of SO2 emissions." (GAO 1984) (6)

"...the fact...that wet nitrate deposition has increased in recent years, a period when increases in NOX emissions were occurring, is a demonstration of at least partial proportionality between NOX emissions and nitrate deposition, though not necessarily exactly 1:1." (GAO 1984) (6)

6. EFFECTS ON AQUATIC ECOSYSTEMS

"...we have set out the strong circumstances supporting the relationship between acidification, of which acid precipitation is a major cause, and fish populations of lakes, principally in Scandinavia, Scotland and northeast America." (ERL 1983) (5)

"...in susceptible areas of Europe and North America, present atmospheric depositions of acidifying compounds have reached levels at which they generate detrimental changes in water chemistry and hence in aquatic life. The sulphur compounds are recognised to be of decisive importance .... It has been proven, however, that nitrogen compounds may also play a significant role in short-term events and, should emissions continue to increase, nitric acid not absorbed by the ecosystem will in the long run increase the acidification of surface waters." (UNECE 1984) (23)

"In southern Norway...1750 lakes have lost fish populations and 900 others are seriously affected. In southern and central Sweden,...the fisheries of an estimated 18000 lakes with pH lower than 5.5 are now affected." (Stockholm Conference 1982) (15)

"Estimating the sensitivity of waters is not solely a question of pH. One criterion widely used is 'alkalinity', an approximate measure of the bicarbonate concentration in the water, which has ben taken of an index of the ability of the watershed to neutralise acid." (GAO 1984) (6)

"...soil supplies of materials such as calcium and magnesium ions (which can be exchanged to neutralise acids in the weathering process) or the soil's ability to absorb sulfate ions may be diminished enough by many years of processing deposited acids so that the acid-neutralising capacity of the soil would be exhausted, or at least lowered to a point where it can no longer protect the surface waters from acidification." (GAO 1984) (6)

"An important consequence of acid deposition on water chemistry and conditions of aquatic life is the mobilisation of aluminium. Observations strongly suggest that the association of aluminium peaks with acid events in streams and lakes is a major factor involved in the decline of fish populations." (UNECE 1984) (23)

"Scientists believe that fish do not successfully reproduce in some clear acidic waters largely because toxic aluminum concentrations may occur as acidity increases." (NAPAP 1983) (19)

"...while all the scientists we contacted agreed that acidification is a cumulative process, some suggest that a lake's adjustment to a change in the acid deposition rate is relatively fast -- possibly taking only a few years -- while others suggest the process could take a number of decades." (GAO 1984) (6)

7. EFFECTS ON FORESTS

"Damage done by acid air pollutants to forest vegetation can be of two kinds: direct, affecting leaves and stems, and indirect, altering the root environment." (Stockholm Conference 1982) (15)

"The recently reported forest damage in an estimated 1 million hectares of central Europe seems to be related to (among others) the direct effects of gaseous pollutants and soil impoverishment, and toxicity arising from very large amounts of wet and dry deposition. In contrast, in southern Scandinavia, with smaller total amounts of deposition and markedly less atmospheric SO2 and NOX, tree growth has not yet been shown to be adversely affected. The direct effects of gaseous pollutants are likely to decrease rapidly if atmospheric loadings are decreased. On the other hand, the indirect effects, with their associated soil changes, are likely to persist or possibly intensify even if present acid and acidifying inputs are decreased." (Stockholm Conference 1982) (15)

"...air pollutants, especially SO2 and NOX and their conversion products, are considered, singly or in combination with other factors, to be a major cause of existing and increasing damage." (Munich Conference 1984) (22)

"Observed declines in tree growth and forest dieback in areas with elevated pollution levels and high acid deposition have heightened concern about the potential negative effects of acid deposition and other air pollutants" (NAPAP 1983) (19)

"A causal link between deposited acidity and forest effects has yet to be demonstrated, however, and other factors including water stress and elevated summer ozone concentrations, have also been identified as possible causes." (Warren Spring 1983) (18)

"While the initial concern was about sulphur dioxide and acid deposition, many scientists currently believe that nitrogen oxides and oxidants such as ozone may be contributing to the observed forest changes." (NAPAP 1983) (19)

"The connections between forest damages and emissions are very complex,...however, in reviewing the new forest damages which have occurred at considerable distances from urban conglomerations and emission sources, the Council concluded that ... there would be no <u>new</u> forest damages without air pollutants, and that the direct influence of air pollutants (affecting the leaves and stems) is more decisive than the route via the soil." (CEA 1983) (20)

"In the Federal Republic of Germany 'die-back' of spruce has been associated with deterioration of fine feeder roots in soils with high concentrations of mobilised aluminium and heavy metals. Because these observations reveal damage similar to that caused to agricultural crops by aluminium (concentrations of aluminium are of an order of magnitude lower in agricultural than in forest soils), they may be of wider significance.

Since large areas of the productive forests of Canada and northern Europe rest on relatively poor soils, the increased loss of even small quantities of soil cations could appreciably affect long-term soil fertility - a matter of considerable concern. In parts of central Europe, there is already evidence of aggravation of magnesium deficiencies." (UNECE 1984) (23)

"...acidic deposition ... may be acting in combination with other factors (including droughts, which stress the tree population, or highly phytotoxic gaseous pollutants, such as ozone and sulphur dioxide)." (EPRI 1983) (17)

"Most scientists believe that forest damage stems from some combination of droughts, gaseous pollutants (ozone, sulfur dioxide and nitrogen oxides), acidic deposition, trace metals, long-term tree population cycle, and pests... Moreover, these stresses are interactive and interdependent." (WRI 1985) (24)

8. EFFECTS ON MATERIALS

"Rates of corrosion and degradation of building material can be accelerated by increased acidity." (NAPAP 1983) (19)

"Several scenarios and mechanisms exist for damage to materials from acidic deposition including both long-range transport and local source emissions. Without question acidic deposition causes significant incremental damage to materials, beyond that caused by natural environmental phenomena." (EPA-CARP 1983) (21)

"The corrosive effect of the dry deposition of sulphur dioxide is well documented but less information is available for other pollutants including rainfall acidity and, as yet, their relative importance has not been fully established." (Warren Spring 1983) (18)

"Damage to buildings arises only from relatively high concentrations of SO2 close to urban and industrial emission sources. (ERL 1983) (5)

"The sulphur compounds in the atmosphere contribute to serious damage to historical monuments and buildings of sandstone, limestone and marble..." (UNECE 1984) (23)

"Nitric acid can be particularly damaging to metals because the compounds formed when nitric acid reacts with metal surfaces are generally soluble and are easily removed, exposing underlying layers to deterioration." (GAO 1984) (6)

"...it is quite possible that consideration of damage to materials could give economic justification for SO2 and/or NOX emission limits that are more stringent than those presently in place." (GAO 1984) (6)

9. EFFECTS ON CROPS AND SOILS

"Scientists have found little conclusive evidence for major direct effects of acid precipitation on vegetation at current deposition levels. The direct effects on crops appear less significant than those related to other air pollutants such as ozone." (NAPAP 1983) (19)

"Soil scientists generally believe that most managed agricultural soils are not vulnerable with respect to acid deposition." (NAPAP 1983) (19)

"Although early studies suggested that acidic deposition might cause crop damage, later studies on field-grown crops have resulted in the consensus that crops face no danger from acid rain ... although it may possibly work in combination with other atmospheric pollutants, such as ozone, to damage plants." (EPRI 1983) (17)

10. EFFECTS ON HUMAN HEALTH

"Potential threats to humans may occur as a result of:

-- exposure to a higher heavy metal intake from drinking water provided in lead or copper plumbing;
-- exposure to a higher heavy metal intake, particularly mercury and cadmium from the bioaccumulation process in aquatic food chains." (ERL 1983) (5)

"No definite connections have yet been made between acid rain and human health, but the few data available suggest that if there is a problem, it would apply under limited conditions. Householders who draw their water unmonitored and untreated from rainwater cistern systems may be exposed to metals that the rain corrodes out of water pipes. Those who draw their water from shallow wells may also be at risk if aluminum or other metals leached from the soil by acid rain find their way into the ground water supply." (EPRI 1983) (17)

"Epidemiological studies have provided important evidence of a relation between air pollution and health. When the levels of air pollution have been high, the relation was repeatedly observed. At current levels, however, whatver relation there may be is essentially obscured by the background 'noise' of confounding factors." (UNECE 1984) (23)

11. THE COST/BENEFIT BALANCE

"...The uncertainty about the prospects of damage from acid deposition -- the dose-response relationship -- is so great that it prevents identifying any narrow range of estimates of the benefits of acid deposition control at this time." (GAO 1984) (6)

"Ongoing and planned or proposed research is likely to provide better knowledge on damages, but only after some years." (GAO 1984) (6)

ANNEX 4

WHAT RECENT REPORTS SAY ABOUT WAYS TO DEAL WITH THE ACID RAIN PROBLEM

1. STOCKHOLM CONFERENCE 1982 (15)

"Further concrete action is needed within the framework of the Convention to reduce air pollution, including long-range transboundary air pollution. Such action should include:

a) The establishment and implementation of the concerted programmes for the reduction of sulphur emissions to be a matter of urgency. Similar actions should be taken as soon as possible for reducing emissions of nitrogen oxides;

b) The use of the best available technology which is economically feasible for the reduction of sulphur emissions. Flue gas desulphurisation (FGD) has been proven as a main SOX control technology. Alternative technologies like the use of clean fuels, fuel cleaning and process modification are also applied. In new and, where practicable, rebuilt installations, such as power stations, the above-mentioned technologies should be introduced. Due to the consequences for transboundary pollution high stacks in place of emission control devices must today be considered an obsolete abatement mechanism for sulphur emissions. Best available technology which is economically feasible should also be applied to reduce NOX emissions from both stationary and mobile sources;

c) In applying these technologies account should be taken of the need to minimise waste products and polluting discharges to other environmental media;

d) The support for research and development of advanced control technologies, appropriate for reducing emissions of SOX and NOX as well as the use and transfer of such technologies;

e) The further development and implementation of energy conservation measures;

f) The further development of the North American monitoring programmes as well as the European Monitoring and Evaluation Programme (EMEP), inter alia through better geographical coverage; improved emissions data; standardisation of sampling and measurements and improved modelling."

2. MULTILATERAL CONFERENCE ON THE ENVIRONMENT, MUNICH 1984 (22)

"The following resolutions were adopted by the Munich Multilateral Conference on the Environment:

Agrees that international co-operation, within the framework of the work programme of the Executive Body for implementing the Convention, must be intensified for combating damage to forests, soils, water bodies, ecosystems, crops and vegetation and to materials including historical monuments;

Agrees that national measures top reduce air pollution including long-range transboundary air pollution must be continued and appropriately intensified in order to prevent damage to forests, soils, water bodies, ecosystems, crops and vegetation as well as materials including historical monuments;

Deems it necessary that the rational and economic use of energy be regarded as a prime objective of energy policy and contributes inter alia to the reduction of damage to forests, water bodies, ecosystems, crops and vegetation as well as materials including historical monuments;

Recommends that increased use be made of the best available technologies which are economically feasible, and which have been demonstrated for manufacturing low polluting fuels, improving combustion processes, and reducing pollutant emissions from stationary or mobile sources and that further development of such procedures be promoted;

Requests that at its second meeting, the Executive Body for the Convention as a matter of highest priority adopts a proposal for a specific agreement on the reduction of annual national sulphur emissions or their transboundary fluxes by 1993 at the latest having regard to the facts that a number of countries have committed themselves to implement reductions of national annual sulphur emissions by at least 30 per cent as soon as possible and at the latest by 1993, using 1980 emission levels as a basis for the calculation of reduction; a number of other countries announced their readiness and intention to reduce their transboundary fluxes of sulphur emissions by 30 per cent by the same date at the latest;

the Contracting Parties have recognised the need to decrease effectively the total annual emissions of sulphur compounds or their transboundary fluxes by 1993, using 1980 emission levels as the basis for the calculation;

Deems it necessary that total annual emissions or transboundary fluxes of nitrogen oxides from stationary and mobile sources be effectively reduced by 1995 considering that a number of countries have committed themselves to implement such reductions at an earlier date;"

3. ENVIRONMENTAL RESOURCES LIMITED REPORT 1983 (5)

"It is clearly not possible to make an overall judgment on this matter given the unknowns and uncertainties in the degree of possible damage being caused by acid pollutant emissions. However, some uncertainty will always exist and should not be an excuse for postponement of any action."

"From the analysis of emission trends and their sources, in relation to possible effects, it follows that, if a substantial reduction in SO2 and NOX emissions should be considered necessary with a 10-15 year time period, control action would need to:

i) be directed at most major categories of fossil fuel consumers;
ii) include existing as well as new consumers."

4. NATIONAL ACADEMY OF SCIENCE REPORT 1983 (16)

"The implications of our findings and conclusions for choosing among possible emission control strategies, should they be deemed necessary, are limited. We do not believe it is practical at this time to rely upon currently available models to distinguish among alternative strategies."

"...useful information about the delivery of acids to ecologically sensitive areas by transport and transformation processes can be determined more quickly by direct empirical observation in the field than by other means...the [field] studies are likely to provide basic phenomenological evidence with sufficient reliability to form a basis for improving the near-term strategy for dealing with the problem of acid deposition in eastern North America. Indeed, the data are essential to enhance theoretical understanding and to develop improved deposition models. In the long term, however, the ultimate strategy for dealing with acid deposition will depend on the application of realistic, validated models."

5. ELECTRIC POWER RESEARCH INSTITUTE REPORT 1983 (17)

"This recent push introduces a fundamental choice of investment strategies for decision-makers -- whether to increase the investment on older, less efficient plants where controls are not an integral part of the design or to reserve investment capital for systems now under development that combine superior environmental performance with improved energy and operational efficiency.

If, for example, the nation's decision-makers choose to deal with the problem by electing an arbitrary and rapid reduction in SO2 emissions of 10 million tons per year (as proposed by legislation), the control options become effectively limited to those currently available: plant retirements, low-sulphur coal blending, coal cleaning, and flue gas scrubbers. This approach would involve plants totalling about 100,000 MW of capacity. Making allowance for many kinds of uncertainty, it might cost $11-15 billion a year to execute, even if various institutional and contractual limitations can be resolved. The large out-of pocket costs imposed by this approach are primarily due to heavy reliance on scrubbers for more than half of this capacity.

Alternatively, strategies that allow for more gradual reductions in emissions would both open the range of retrofit control options and encourage the use of those that cost least-- particularly retirements, blending, and cleaning. Retrofit options under development, such as limestone injection and low-NOX burners, may provide somewhat more cost-effective control but are probably limited in application and therefore have less potential for emission reduction.

Both of these scenarios offer something of a Band-Aid solution, and an expensive one at that. Besides the tremendous capital costs of add-on equipment or internal plant modification, most of the options incur additional penalties in efficiency and/or reliability.

A still longer-term view would include the approach of preserving capital to speed the development and transition to new coal generation systems that are inherently clean and more energy-efficient than current plants. New systems, such as fluidised-bed and gasification-combined cycle plants, represent the concept that the use of coal for power generation is not fundamentally in conflict with a clean environment, and thus have strong appeal as an ultimate solution. The potential for these types of generation is great enough to introduce another trade-off consideration for decision-makers: although they are at least several years from commercial readiness, they allow emission reductions to follow naturally from the current economic and environmental evolution of coal-fired plants. This would eliminate costly Band-Aid approaches that serve to freeze technology in today's plants and would, in the long run, provide improved emissions control in a more cost-effective manner."

6. <u>COUNCIL OF ECONOMIC ADVISERS (FRG) REPORT ON FOREST DAMAGE AND AIR POLLUTION 1983 (20)</u>

"The long-term policy calling for reductions of the pollution load shall be continued. ... not forgetting the commitment ... to reduce the annual total SO2 emission by about one-third within the next decade."

"The cleaning up (retrofitting or closing down) of existing plants ... represents the really decisive measure for the reduction of pollutant loads"

"In the future, particular attention must be given to the reduction in the emission of nitrogen oxides. ... The efforts to reduce the nitrogen oxide emissions from motor vehicles must be intensified."
"Research on the causes behind the death of forests must be intensified."

7. <u>GENERAL ACCOUNTING OFFICE (GAO) REPORT 1984 (6)</u>

"Mitigation actions taken where deposition occurs, such as liming of lakes, can prevent damage in some cases. However, they have limited capabilities both because they cannot control all kinds of damage, and also because they cannot be applied economically to large unmanaged areas such as forests."

"If deposition reduction is desired, to control the risk of damage stemming from acid deposition, the greatest reduction in risk would come from lessening the deposition of acidic sulphur compounds, which could be accomplished best by reducing SO2 emissions."

"Because deposition at almost any location includes significant contributions from sources spread over a wide area, emission controls intended to produce substantial reductions of acid deposition, even at one location, would be needed over a wide area rather than at one source or a narrowly localised set of sources."

"While cost-benefit analysis can often aid in identifying a range of economically efficient pollution control policies, current scientific uncertainty about the value of the benefits expected from proposed levels of acid deposition control is so great that cost-benefit analysis is of limited value in deciding whether additional controls on SO2 emissions would or would not have benefits that justified their costs."

"Marginal costs of emission reductions increase at greater levels of reduction, so that if reductions were chosen seeking to eliminate damage completely, the last increments of reduction would be very costly compared with the last increments of damage prevented."

"The control method of switching to low-sulphur coal may or may not offer lower overall costs. However, it would have indirect costs, in the form of employment shifts between regions, which would disproportionately affect limited areas where high-sulphur coal is mined."

"Agreement on an approach to the acid deposition problem is likely to be aided by separating the question of when and in which areas of the country control actions should occur, from the question of how the control actions are to be financed."

"Because the Clean Air Act currently focuses on concentrations of pollutants near their sources, any air pollution control approach to deal with acid deposition in this century would necessitate additions to, or a basic reorientation of, the ambient air quality standard approach in the present act."

"The dispute persists over whether it would be advisable to establish emission controls promptly to reduce acid deposition or to wait further. However, at a minimum, having control plans ready could save time, and therefore spare resources, if/when a need for rapid action becomes evident."

"Further scientific work on acid deposition will be needed for a number of years, no matter what decisions are made on control actions in the short run."

8. <u>WORLD RESOURCES INSTITUTE REPORT 1985 (24)</u>

"... The U.S. Environmental Protection Agency, working with California, Washington, and Colorado, under authority of the Clean Air Act, should formulate a regulatory plan for reducing NOX emissions from mobile sources."

"... the U.S. Congress should not extend the Non-Ferrous Smelter Order (NSO) exempting smelters from the emission-reduction requirements of the Clean Air Act beyond the Order's current expiry date of December 31, 1987."

"In addition, the U.S. Environmental Protection Agency, in the context of discussions with the Mexican Secretariat of Urban

Development and Ecology, should negotiate an agreement for controlling emissions from Mexican smelters ..."

"State and federal air pollution regulatory authorities should amend their regulations for permitting new facilities, making the cumulative impact of emissions from a proposed facility on acidic deposition in sensitive regions a siting consideration."

"... the U.S. Department of Energy and the states should explore the roles of energy conservation and renewable, non-polluting energy resources in the long-term reduction of SO2 and NOX emissions."

A NOTE ABOUT THE AUTHOR

Dr. Ian Torrens holds a Ph.D. in Physics from the Cavendish Laboratory, University of Cambridge in the United Kingdom, and has spent the earlier part of his career in research in the field of nuclear reactors. Between 1974 and 1980 he was involved in the work of the International Energy Agency of the OECD, notably as Head of the IEA's Oil Industry Division. Since 1980 he has headed the Resources and Energy Division of the OECD Environment Directorate, which is responsible for work in the fields of energy and environment, air pollution, water management and hazardous wastes. He is the author of numerous articles and papers in the environmental field, particularly with regard to coal and the environment, and to air pollution including acid rain.

SCHEMATIC VIEW OF THE ACID RAIN PROBLEM

URBAN/RURAL TRANSPORT

TRANSFRONTIER TRANSPORT

EMISSION SOURCES *(stationary and mobile)*	FUELS	MAJOR POLLUTANTS	EFFECTS	UNCERTAINTIES
Power plants	Coal	Particulates	Property (materials)	Quantitative link between deposition and emissions (how much of what comes down where)?
Industry	Oil	Sulphur oxides – SO_x	Ecosystems (forests, lakes, crops)	Magnitude of effects attributable to deposition
Transport	Gas	Nitrogen oxides – NO_x	Health	Valuation of effects (damage costs)
Residential/commercial		Hydrocarbons – HC	Visibility	

CONTROL STRATEGIES
(not mutually exclusive)

1. **Increase efficiency of energy use**
2. **R & D to increase knowledge of causes/effects**
3. **Emissions standards for air pollutants**
   - **uniform or variable**
   - **targeted on specific sources**
   - **national or international**
   - **new plants or existing plants**
4. **Setting emission reductions on regional or national basis (possibly with emissions trading)**

CONTROL TECHNOLOGIES

- **Low sulphur fuel**
- **Fuel cleaning**
- **Combustion modification for NO_x control**
- **Limestone injection for SO_x control**
- **Electrostatic precipitators or baghouses for particulate control**
- **Flue gas desulphurisation**
- **Catalytic converters on vehicles to control NO_x and HC**
- **New technologies (R & D)**

COSTS/BENEFIT ISSUES

- **Cost of pollution controls**
- **Environmental damage costs**
- **Level of control to balance these**
- **Who pays for pollution control?**
- **Who pays the damage costs?**

ECONOMIC IMPLICATIONS OF INCREASED CONTROL

- **Increased energy costs (10-20 per cent on new power plant costs; much less on electricity costs to consumer)**
- **Reduced margin between coal and oil prices (but oil also requires pollution control)**
- **Use of economic resources for pollution control (only a problem in a stretched economy; otherwise adds to GDP)**
- **Lower materials maintenance and repair costs**
- **Increased forest and lake productivity**
- **Economic benefits due to greater visibility**
- **Improved public health and lower health charges**
- **Lower atmospheric lead concentrations if catalytic converters are used on vehicles**

HAUFF: ACID RAIN

OUR RECOMMENDATION

Knowledge is incomplete and uncertain

Rescue a drowning person

Hearing: "Without air pollution there would be no die-back of the forests"

It is complex: Acid Rain, Ozone, Aluminium, Heavy Metals

There is no simple cause

BUT, we are in a situation like somebody who has to rescue a drowning person

To act or not to act - this is the question

(1) Energy Options (T 26)
    Energy Efficiency
    Fuel Substitution
    Renewable Sources
    Environmentally Favourable Energy Option
    Institutional Links
    Integration of Environmental Cost
    Incentives

(2) Prevention and Control of Emissions (T 29)
    Power Plants
    Smaller Industrial Installations
    Vehicles

(3) Liming (Hearing P 12)

(4) Intensify Research (Alibi)
    Tropical forests; literally nothing is known (G.2)(T 46)

(5) What should we learn from the acid rain crisis?
    - Regional
      Other threats

Stanovnik: Hazardous waste

Recommendations:

(1) Reduce the amount of hazardous waste produced
(2) Recycling of hw
(3) Product change (multinationals)
(4) No dumping in global commons (air, water, and other "not-owned" commons)
(5) Transport notification, monitoring
(6) Advisory Panel on industry, Decouple waste and growth
(7) Bring in ICC to draw up guidelines/convention