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Central Bureau of Statistics, P.B. 8131 Dep, 0033 Oslo 1, Norway

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Environmental Indicators

KNUT H. ALFSEN, KJELL ARNE BREKKE, FRODE BRUNVOLL, HILDE LURÅS, KARINE NYBORG AND HANS VIGGO SÆBØ.[1]

FSU

Økonomi og økologi

Abstract

The report discusses possible logical structures and content of a set of environmental indicators for Norway. The emphasis is on structure; proposals for specific indicators and data presented are of a more preliminary nature.

[1]Thanks to Asbjørn Aaheim of the Central Bureau of Statistics (CBS) who has participated on most of the works sessions where the ideas, presented in this report, were developed. Also thanks to Marit Kromberg from the Norwegian Directorate of Health, Bjarne Sivertsen, Knut Grønskei and Leif Otto Hagen of the Norwegian Institute for Air Research (NILU), and Gabriel Kielland of the State Pollution Control Authority (SFT) for helpful discussions on the health related indicator. Signe Nybø of the Directorate for Nature Management (DN) participated in the discussions on biodiversity, while Jan Fuglestvedt (CBS) has had a decisive influence on the discussions of the ozone indicator and the indicator of climatic change.

Content

1 Background and introduction

1.1 The research program *Economy and Ecology* and methodological issues.

After the publication of the report "Our Common Future" from the Brundtland Commission in 1987 (WCED, 1987), Norwegian research councils established a committee to elaborate the follow up of the report by the research community. The committee recommendations lead to the establishment in 1991 of a broad 5-year research program, called "Economy and Ecology"[2]. The program encompasses both natural sciences such as biology, earth sciences, etc., as well as economics. The overall aim of the program is to "develop planning tools for a sustainable development". The research program is organized into 5 sub-programs. The issues covered are agriculture and pollution, multi-species fisheries management, society - its use of energy and the environment, and ecology and development. In addition a fifth subprogram was given the responsibility for research on methodological issues relating to all of the above fields.

It is within this last subprogram the issue of environmental indicators has been addressed. This is a report from the subprogram on the work carried out so far.

1.2 What is an *environmental indicator?*

An environmental *indicator* is a number[3] that is meant to indicate the state or the development of important aspects of the environment. An indicator without a unit of measurement is an *index*. An index is often constructed from several indicators weighted together to capture the total impact on an aspect of the state of the environment. A *leading* indicator to an environmental indicator, is an indicator that gives early warning of the development in the environmental indicator.

In this report we will only consider environmental indicators defined in a narrow sense. The focus will be on man-made (anthropogenic) impacts on the environment. We will not develop indicators of reserves and use of natural resources or development in social or economic factors. We recognize, however, that the distinction between natural resources and the environment is ambiguous. We treat canopy density of forests as an environmental factor, while it may be equally natural to consider it as an aspect of the development in the renewable resource stock. We will also stress that we do not consider natural resource indicators to be less important than environmental indicators.

[2] The program is supported and directed by the Joint Norwegian Committee of the Research Councils (FSU).

[3] Usually an indicator will be presented as a set of numbers, for instance a time series or a geographical cross-section. Strictly speaking, the term indicator refers to a specific number along the time or space dimension. However, we will employ a less precise language and denote the whole set of numbers as an indicator.

1.3 On sustainability

We will make no attempts to characterize "sustainable development" as such or to develop "indicators of sustainable development". Since a deteriorated environment is perceived as a threat to sustainable development, the concept of sustainable development is often in focus when considering the development over time of the environmental indicators. On the other hand, to figure out whether a development is sustainable or not, we need to know a lot more than the development in environmental variables. Unfavourable development in areas like crime, culture or education may have considerable welfare effects in the long run, unless the trend is reversed. Without a precise definition of "sustainability," it is not clear that such aspects of the development of a society are irrelevant for sustainability. We will stress that it is beyond the scope of this report to operationalize the concept of sustainable development, or to figure out whether or not the development is sustainable, although we recognize that environmental factors are crucial for evaluating sustainability.

To evaluate the sustainability of the development, we need models of very long term economic development, integrating environmental aspects and natural resources. Development of such models will be an essential part of future work in the subprogram on methodological issues under the Economy and Ecology program. The assessment of different development paths is an important aspect of such models. We hope that it will be possible to let at least some of the indicators developed here be central parts of the output from the models. Thus the indicators will become an integrated part of a model system that can be used to evaluate sustainability of the development. Resource accounting and environmental information will be essential input for the models.

1.4 Users of environmental indicators

We consider anybody who is concerned with the development of the natural environment a potential user of environmental indicators. Different groups of users will obviously differ in their need for information and in their ability to understand and make use of a specific type of information. We recognize that there already exist lots of available information on the state and development of the environment. *Thus we do not expect that a set of environmental indicators will give environmental experts new information.* On the other hand, we lack a general, condensed description of the environment that is easily understood even without advanced knowledge of disciplines like ecology, chemistry, biology or medicine. Thus we consider as users of the environmental indicators, non-experts that are concerned about the environment.

1.5 Publication policy

Several countries and international organizations regularly present "state of the environment" reports. Such reports correspond more or less to "state of the economy" reports, like the Economic Survey presented annually by the Central Bureau of Statistics in many countries. The publication is meant for a non-expert audience.

Since environmental development is closely connected with economic development, it would be natural to present the set of environmental indicators in the Economic Survey publication. It also will be natural to include the indicators in reports on environmental development, like environmental statistics publications.

1.6 Requirements of the indicators

Below we point out some important issues that are relevant when we select candidates for indicator sets and the individual indicators. Some of the points are based on a list of requirements in Liverman et al. (1988).

1.6.1 General overview

The set of indicators should not only give information on the development in specific environmental problem areas, but should also give, as far as possible, a general impression of the general state of the environment. Care should be taken not to include only "problem areas". Also areas of progress should be included to avoid an unnecessary negative bias in the indicator set.

If the list of indicators is too long, the public debate will most likely focus on only a few of them. In order to provide an overview of the general state of the environment, the *list of indicators should be short.*

1.6.2 Reference points

Information about the environment may be hard to evaluate by itself and in isolation. We would like to answer questions like, How bad or good is this really? Is it possible to do better? To answer such questions we need points of reference. Thus it is important to be able to compare the situation and development in different countries. For similar reasons it is important to be able to present reasonably long time series of the indicators.

Knowledge of the state and development of the environment in other countries would tell us if the state of the environment in Norway is better than in other countries. Also, it would tell when other countries have been able to solve problems that are unresolved in Norway and vice versa. Preferably the set of indicators for Norway should be the same as or close to the set of indicators used in other countries. However, there are yet no generally accepted standards for environmental indicators.

There are natural sources of emissions and discharges for many important pollutants, e.g., emission of SO_2 from volcanos and oil spills from reservoirs under the sea. Even extinction of species is a natural process. It is thus important to be able to compare man-made (anthropogenous) impacts with natural variations. How large are the present changes in biodiversity compared to natural variations? Thus it would be interesting to know the state and development of the environment over an extended period of time, preferably from the time before industrialization. Unfortunately it will rarely be possible to construct such long series, but still the length of the time series is an important aspect in the choice of indicators.

1.6.3 Sensitivity

The indicator should be sensitive to changes in the state of the environment that it is meant to indicate. We will also require that the indicator should be sensitive to changes in the composition of the basic structures e.g., by focusing on the marginal areas.

Unfortunately, indicators that are sensitive to the changes we want to measure, may also be sensitive to other changes. Thus, it is also preferable that the indicator distinguishes natural variations from changes in trend.

1.6.4 Early warning

Preferably, the indicator should give an early warning about irreversible changes. This is not an absolute requirement. We cannot predict what will happen in the future without a model of the development. With models we can forecast the development in the indicators. Such forecasts may give an early warning even if the indicator alone does not.

1.6.5 The indicators should be easy to interpret

Since we have defined the general public as the main audience, we must require that the indicators should be relatively easy to interpret. At least, interpretation of the indicators should not require advanced knowledge of disciplines like biology, ecology, earth sciences or economics. This requirement must sometimes be balanced against a requirement of scientific validity. For instance, man-made climatic change is related to changes in radiative forcing in a scientific relatively precise manner. But it may be difficult for the lay person to relate to the concept of radiative forcing. Much easier to grasp is changes in global mean temperature, but the link between temperature variations and the man-made greenhouse effect is much more uncertain scientifically.

1.6.6 Result control

Norway has signed environmental agreements concerning national emissions of several important air pollutants as well as discharges to the North Sea, and the government has stated explicit goals for the development in other areas. Thus, information is needed for verification of agreements and target achievement. This will sometimes require detailed information that is not suitable to present in a condensed set of indicators. Besides, technical verifications are done by experts who can collect and process detailed information. The indicators presented in this report are not primarily meant for verification of target achievements, even if the comparison with targets is an important issue concerning several indicators.

1.6.7 Analyses

An adequate response to environmental problems requires that we can model the connection between economic activity and the environment. Preferably, it should be possible to present the environmental impact of different economic policies in terms of the development of the environmental indicators. Other kinds of analyses will also be of interest, like analyses of environmental impacts on human health or analyses of the causes of a deteriorated environment. The need for linkage to different kind of models should be kept in mind when we select the set of environmental indicators.

1.6.8 Data

It should be possible to find data for the indicator at acceptable costs. Furthermore, the data should preferably be non-controversial.

2 The importance of a good environment

Before we start discussing the choice of a particular set of environmental indicators, we wish to discuss more closely *why we need such indicators*. We have stated that the indicators are meant to provide easily understood information to non-experts who are concerned about the environment. But what kind of information does this group need? This is related to the basic question: "why are we concerned about the environment?".

In this section we will point out what we believe are the main reasons why people are concerned about the environment. We do not necessarily support all the points of view listed below, but we believe that it is important to try to understand the motivation behind the concern in order to be able to come up with a reasonably satisfactory indicator set.

2.1 Health

Health effects of pollution is obviously a legitimate reason for trying to improve the quality of air or drinking water. There are reasons to believe that many people suffer from cancer or asthmatic and other diseases because of pollution. However, almost any problem in a society may be considered as a health problem in the final analysis. People may, for instance, become ill from worrying about the well-being of future generations. In this context, we want to distinguish health from other reasons for concern about the environment. Thus, in the following, health problems only refer to physiological diseases directly caused by pollution and to problems caused by noise.

2.2 Economic damage

Pollution causes economic damage. Important examples are increased corrosion of buildings and other capital equipment, and decreasing productivity of the labour force due to increasing health problems. We do not, however, believe that this is the most important reason for most people's concerns for the environment. Furthermore, these effects are already accounted for in economic indicators like Gross Domestic Product (GDP) or Net National Product (NNP), which will not be discussed in this report.

2.3 Recreation, aesthetics and culture

The heading of this section is a mixture of several important reasons for concerns about the environment. We have grouped them under the same heading, since we found it very difficult to draw a clear distinction between them. It is valuable to have the possibility to go fishing, take a walk in the forest, go hiking, or simply to have the view of green grass and trees. Furthermore, silence and the sound of nature can be very pleasant and it may be a loss of cultural treasures if old buildings are damaged by pollution. We believe that these are all important reasons why people are concerned about the environment.

2.4 Increased knowledge and awareness

Better knowledge and more awareness of environmental problems can in itself easily generate increased concern for the environment and demand for further environmental information. Media exposure of environmental problems, often in other parts of the world, leads to questions on how it is with our own local environment.

2.5 Uncertainty and the long term perspective

We know what we have, but we do not always know what we will get. Is this the core of conservatism as a political ideology? It may be rational to have aversion against uncertainty, or rather ignorance. The ignorance about future consequences of economic and environmental policy is an argument in favour of ecological conservatism: The environment should be changed as little as possible.

2.6 Ethical values and the intrinsic value of nature

Nordhaus (1991) and others have claimed that even if the greenhouse effect causes significant increases in global temperature, the economic cost of these changes will be minimal. This is used as an argument for a claim that reduction of CO_2 emission is not worth the cost. Some people react to this argument in a way that is hard to interpret as anything but moral anger. What is the reason for this moral anger? We can think of several partly related reasons.

In a Christian world view, God created the world. To consciously make significant changes to the world's climatic system, claiming that the benefits are higher than the cost, is to play the role of God. Man does not have the moral right to do this.

Nature represents the basis for all natural resources, including genetic resources. Thus, nature represents the ultimate basis for human existence. We love our children. We even care about how things will go for them after we are dead and gone. Perhaps some people feel a similar kind of love to our planet? Can we even have an instinct to protect the system we are a part of?

3 Principles for classification of environmental indicators

The totality of environmental problems is very complex. On one hand the same problem may have several causes. For instance, the risk for asthmatic diseases increase by exposure to high concentration of several gases, like NO_x, ozone, SO_2 and of particles. On the other hand, the same emission may cause several problems. Emission of SO_2 in urban areas causes health problems and corrosion damage, but the gas may also disperse into the atmosphere and fall down as acid rain, causing fish death in distant lakes. Thus the different aspects of the problem are interconnected in a complex way.

A good classification of environmental indicators would provide a much-needed overview to this problem. We will consider some possible classification schemes below. Unfortunately, any classification scheme will cut problems that naturally belong together into pieces. This is due to the many interconnections between the different environmental problems.

Beside the possible classifications listed below, we may distinguish between indicators of the state or development in the natural environment, and indicators of environmental policy, see table 1. Total area of protected national parks, is an example of an indicator of environmental policy. The focus in this report is to give information about the environment, not about environmental policy. Thus we have disregarded indicators of environmental policy.

Table 1 Grouping of environmental indicators

Stress on the environment	Response: State of the environment
Policy measures meant to reduce environmental stress	Policy measures meant to maintain or improve the state of the environment

The list of possible classification schemes below can be considered as a classification along a causal dimension from stress on the environment to environmental responses:

1. The stresses on the environment often come from emissions or discharges of pollutants. A possible approach is thus to classify the indicators according to the pollutants.

2. Alternatively, we may classify the emission sources according to the economic sector responsible for the emissions.

3. Emissions of pollutants cause increased concentrations of pollutants in the ecosystem. Thus, we may use a classification scheme based on a division of the environment into media or recipients like air, fresh water, sea, soil, etc.

4. Increased concentration of pollutants causes damage to people, animals or plants. The effects are typically different in different parts of the "ecosystem", like urban or rural areas, in the wilderness, etc. Classification of "ecosystems" may be used as a basis for classification of the indicators.

5. We may also classify the problems according to the final effects. The headlines in section 2 (i.e., health, economic damage, recreation, aesthetics and culture, ethical values) may be used as a classification scheme based on welfare effects.

The various classifications mentioned above or related classifications are further discussed in paragraph 3.1-3.4 below, starting from the response side.

3.1 Classification based on effects on human welfare

In section 2 we listed some reasons why people show concern for the environment. The headlines from that chapter may be taken as a classification scheme of environmental indicators. There are, however, several problems with this approach. Many of the categories listed in section 2 are difficult to define precisely. Health problems, narrowly defined, are probably the best defined group. Economic damage is also well defined, but as pointed out in section 2.2 the economic impact of pollution is accounted for in economic indicators, and thus left out in this report. Recreation, aesthetics and culture is a mixture of different problems that are hard to distinguish. The recreational value of an area is obviously dependent upon the aesthetic qualities of the area. Finally 2.5 and 2.6 are more about general ideology than about a specific problem.

Thus the headlines from section 2 do not form an appropriate classification scheme. At least we must disregard 2.5 and 2.6 as a basis for classification[4], since these paragraphs discuss problems where the total state of the environment is relevant. Furthermore we will disregard 2.2 since economic damage is covered by economic indicators. While the headlines from section 2 is not an appropriate classification scheme, a classification based on environmental effects at a more detailed level, is still possible. We will return to this option in section 3.5.

3.2 Classification based on partition of the environment.

The main idea behind this classification scheme is to classify according to *where* the effects of the environmental problem is located. The environmental problems in urban areas are different from the environmental problems in rural areas. The main classification would then be something like:

1. Urban areas
2. Rural areas
3. Forest/wilderness
4. Global problems.

[4] We do **not**, however, disregard environmental conservatism, ethical considerations or culture and aesthetics as important reasons for concerns about the development of the environment.

Like any classification scheme, this would separate problems with common cause or common effects. Emissions of pollutants in urban areas, may also have considerable effects on forests and wilderness areas and global problems. Furthermore, wilderness areas nearby an urban area, is an alternative to available recreational areas.

3.3 Classification based on recipient and problem areas.

The idea here is to classify according to the recipient of the pollution and the type of problem. A possible, and much used, classification is:

1. Air
2. Water
3. Land/Biodiversity
4. Waste

This classification is in fact a mixture of classification according to recipient (air, water, land) and according to problem areas (biodiversity, waste).

A problem with this scheme is illustrated by the interconnection we pointed out in the introduction to this chapter. In this classification the death of fish in freshwater lakes is classified as an air problem, under the subheading transboundary pollution problem. This classification may be natural from a environmental management point of view, but for the general public it may seem strange.

3.4 Other approaches

Other possible approaches are classifications according to type of pollutant or sector. Compared to a classification based on recipients, a classification based on pollutant is a step towards the stresses on the environment. A classification based on sectors causing the emission, will be a further step in this direction. For two reasons we have only briefly considered these classification schemes. Firstly, the priorities chosen in this report is in the opposite direction towards environmental responses, and secondly, these classification schemes have not been much used elsewhere.

3.5 Our choice

That fish die of acidification of lakes, is definitely an environmental problem. But is it an air problem, a freshwater problem, a wilderness problem, or perhaps a recreational problem? It may even be classified as an SO_2 or NO_x problem. Any of these possible classifications may be defended. However, it is not evident that it will add clarity to choose one of them.

As pointed out in section 1.3, we consider non-expert users as our main audience. This makes it natural to choose a classification scheme as close as possible to the final effects, i.e., a classification based on responses. But, as we pointed out above, we have abandoned the idea of a classification in general terms, like the headlines in section 2. We did however leave open the possibility of a classification at a more detailed level, where it is easier to define operational concepts. The following list of environmental problems may be considered as such a classification.

1. Global problems
2. Health problems including noise.
3. Eutrophication
4. Forest and fish damage
5. Contamination
6. Recreation
7. Biodiversity

Note that these issues are closely connected to *responses* to pollution or other man-made impacts. The general philosophy is to select indicators as close to final effects as possible with reasonable reliability. We believe that this list of environmental problems is easily recognizable by non-experts.

On the other hand, we recognize that other kinds of information, like information about environmental stresses, e.g., emissions of different pollutants, are crucial for environmental management. Thus, we propose the development of a condensed system of environmental information which contain additional information to the main environmental indicator set *(response indicator set)*. Within this system a secondary indicator set will contain stress data consistent with the indicators in the main set *(stress indicator set)*. The system will at a later stage also be enlarged to contain a third indicator set covering relevant demographic and economic parameters related to the secondary (stress) indicator set *(structural indicator set)*.

Our choice of main indicator set may seem unconventional at first sight. But during the work on this report, when we considered different alternative schemes for classification, we noted that *we eventually got the same list of environmental problems*, only the heading was different. In any case, some problems got a strange classification, or intersected different classes.

In figure 1 we illustrate some of the connections between our list of problems and the classification schemes described in section 3.2 (partition of the environment) to the right and section 3.3 (recipient and problem areas) to the left.

4 A short summary of some work on environmental indicators in other countries and institutions

In this section we, as a point of reference before presenting our own suggestions for environmental indicators, briefly review some sets of environmental indicators developed in other countries and institutions. They are further commented upon in Aaheim and Nyborg (1991), Nyborg (1991), Alfsen (1991a,b,c) and in Brunvoll (1991).

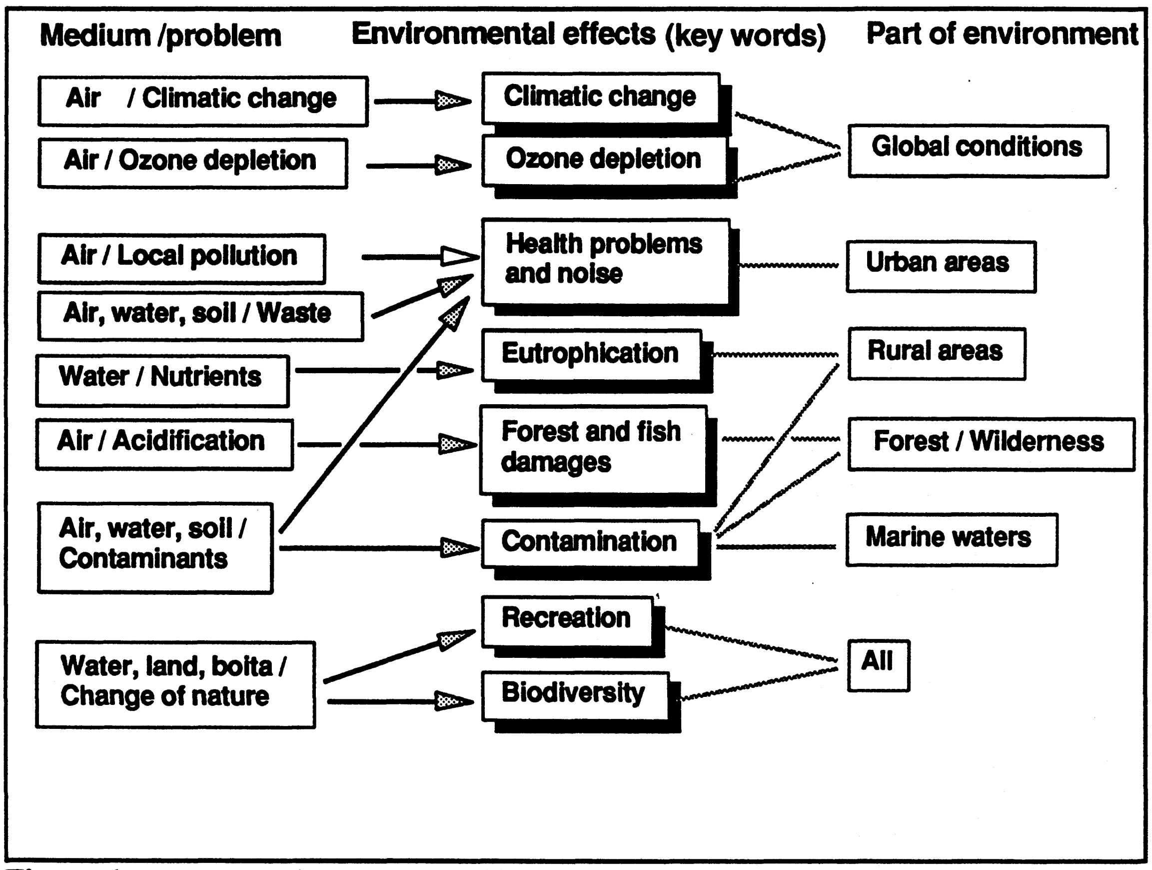

Figure 1 The connection between different classifications.

4.1 Canada

In Canada's *Green Plan*, released in December 1990, the federal government of Canada made a commitment to develop a preliminary set of environmental indicators. The preliminary set, consisting of some 50 indicators covering 18 "issues", was published in January 1991 (Environment Canada (1991)). The indicators are grouped under five main headings:

A. Atmosphere
B. Water
C. Biota
D. Land
E. Natural economic resources.

The classification is thus close to the one described in section 3.3 in this report.

The indicators are meant to be readily understood and used by decision makers and the general public. This is in line with the philosophy in this report. The ultimate aim is, according to the report, to develop a comprehensive state of the environment index like the index for economic activity GDP. We do not share the view that this is a worthwhile goal to aim at. GDP is a measure of economic activity, not a comprehensive index of the state of the economy. Measures of unemployment, income distribution, cost of living and rate of inflation are complementary to GDP as information of the state of the economy. While a summary index may convey some useful information, it must invariably be supplemented by more information if we want an impression of the state of the economy or the environment.

To construct a comprehensive state of the environment index is even more difficult than for the economy. For instance, suppose the concentrations of pollutants are decreasing, and the diversity of species is decreasing too. A comprehensive indicator would have to weight these two trends together in a total index, and conclude that on total the environment has improved or not improved. This is likely to be controversial. In our point of view, the indicators should stimulate debates about the tradeoffs between the different aspects of the state of the environment. A comprehensive index will cover up the important judgments.

4.2 Sweden

Swedish Government Official Report (SOU) (1991): 37 and 38: "Räkna med miljön! Forslag til natur och miljøräkenskaper"[5], proposes a system of environmental indices. The indices are meant to describe the state of different parts of the environment. The system is thus based on a classification system like the one described previously in section 3.2. The environment is divided according to the following list:

A. Agricultural area/Cultivated land
B. Forest
C. Wilderness/Virgin country
D. Coast
E. Fresh water
F. Urban environment/"The city"
G. Global and transboundary environmental impacts

Under each of these headings, 6 to 13 indices are suggested. These indexes are weighted together from underlying parameters. In total the report suggests about 60 indices. It is not proposed to add the indices within a group, but it is pointed at the danger that somebody else will do it.

If the indicators are meant for the general public, we believe that 60 are too many indicators. Most people will never get an overview of this set of indicators. As pointed out in section 2.5 and 2.6 many people are concerned about the environment for reasons

[5] In English: "Taking Nature into Account! Proposed Scheme of Resource and Environmental Accounting." A report by the Commission for Environmental Accounting, Ministry of Finance, Stockholm, 1991.

that refer to the whole picture of environmental development. Thus, an important aspect of a set of environmental indicators is whether or not it gives a correct general impression.

4.3 OECD

The main purpose of the work on environmental indicators in OECD (OECD, 1991) is to develop indicators that will help the integration of decision making with respect to ecology and economy both nationally and internationally. Thus, the OECD indicators seem to be aimed at bureaucrats and politicians, but it is pointed out that an additional important aspect is that they also can be valuable in communication with the public.

We quote from OECD (1991):

> "Three types of indicator sets are currently under development at OECD in order to:
>
> i) Measure environmental performance. This must be done with respect to the level and changes in the level of environmental quality, and the related objectives defined by national policies and international agreements. Summary indicators of environmental performance may also be particularly valuable in responding to the public's "right to know" about basic trends in air and water quality and other aspects of their immediate environment affecting health and well being;
>
> ii) Integrate environmental concerns in sectoral policies. This must be done through the development of sectoral indicators showing environmental efficiency and the linkages between economic policies and trends in key sectors with the environment;
>
> iii) Integrate environmental concerns in economic policies more generally through environmental accounting, particularly at the macro level. Priority is being given to the development of satellite accounts to the system of national accounts and work on natural resource accounts (e.g. pilot accounts on forest resources)."

Comparing the indicators suggested by OECD with the set in this report, we note that our set consists of "summary indicators", mentioned in i). The present work thus has many similarities with the indicators planned under i) above, but with more emphasis on communication with the general public.

The preliminary set of indicators of type 1 developed by OECD is classified under the following headings:

A. Atmosphere
B. Water
C. Biota
D. Land
E. Waste
F. Natural economic resources
G. Miscellaneous

The classification is very similar to that proposed by the Canadians, although the individual indicators differ somewhat.

The second and third type of indicators planned by OECD are meant for integration of environmental policy with economic- and sector policy. We do not suggest any such indicators. On the other hand, the development of integrated environmental and economic *models* is an important part of future work of the subprogram on methodological issues under Economy and Ecology. In order to integrate economic and environmental policies we need to know the environmental effects of different economic policies. This requires economic models. Construction of integrated environmental/economic models is thus an important aspect of the integration of environmental concerns in sectoral policies and in economic policies more generally. On the other hand the construction of such models requires a database for estimation of the parameters in the model. In this respect resource- and environmental accounting may be very useful. A system for natural resource accounting is already established at the Central Bureau of Statistics of Norway and extracts are published annually in the report Natural Resources and the Environment (see e.g. Central Bureau of Statistics, 1991).

4.4 Denmark

The main motivation for elaborating a set of environmental indicators in Denmark seems to have been to encourage the public debate on environmental issues. Thus, the indicators are meant to serve as a brief and pedagogic survey of the state of the environment. The set comprises 30 indicators under the four headings:

A. The City
B. Open Land
C. Air
D. Water.

This classification is a mix between the recipient or problem type classification employed by for instance the Canadians and OECD (see sections 4.1 and 4.3), and a classification based on types of environment proposed by for instance Sweden (see section 4.2). The Danish indicator set makes no attempts at separating stress indicators from more response oriented indicators.

4.5 The Statistical Office of the United Nations (UNSO)

The Statistical Office of the United Nations (UNSO) has recently published a preliminary draft of a System of Environmental and Economic Accounting (SEEA) (UNSO, 1990). SEEA is proposed as a so-called satellite account to the System of National Accounts (SNA). It is based upon a framework for resource accounts in physical units, but includes in addition a monetary valuation of the annual changes in the stock of natural resources and environmental capital. The main valuation principle proposed by UNSO is *the hypothetical costs of avoiding or restoring environmental degradation.*

Basically, the SEEA is an accounting system, and as such it is a collection of detailed data, not an indicator set the way we have defined this term. However, the ultimate aim of the monetary evaluation of changes in the environmental capital stock is to establish an environmentally adjusted net national product, and this measure is clearly an indicator.

Much less clear, however, is the question of what such an indicator in fact do measure. Our objections to the Canadian indicator set are equally valid here; adding together all kinds of environmental issues in one single number is apt to obscure trade-offs and priorities which in our opinion ought to be left open to political judgement. Nevertheless, UNSO is not only proposing to add together monetary values of different environmental issues, but also to measure in one single number both environmental changes *and* economic performance.

Our interpretation of UNSO's proposed indicator is that it is supposed to measure *the level of economic activity which could be sustained without degrading the environment.* This is certainly an important and interesting issue. Still, we have chosen not to establish such an indicator for Norway. The reasons for this can be summarized as follows:

Firstly, we doubt if the question above can be answered adequately by use of accounting procedures. Secondly, we believe that such a measure will be very easily misunderstood. For example, the indicator proposed by UNSO does not reflect actual damage to nature, only the costs which would have been necessary to avoid them. If the environmental policy has really failed, and *cheap* actions which could have prevented *severe* damage have not been taken, the "green GDP" may differ little from the ordinary GDP since the hypothetical costs were low, even if the damage done was substantial, see for instance Nyborg (1991) and Central Bureau of Statistics (1992).

5 The set of environmental indicators

The main set of environmental indicators is primarily meant to give easily understandable general information about the state or response of the environment. For purposes like analysis of links between economic development and the environmental indicators, international comparisons or verification of target achievements, the information provided by these indicators will be incomplete. Thus, we plan to develop a more complete, but still a rather condensed, set of environmental information.

The discussion above has to some extent been centered around two issues; one is related to the dimension going from *stress* to *response*, the other has to do with the degree of *uncertainty* both with respect to data quality and with respect to the linkage between indicator values and the factual state of the environment. Generally, we find stress oriented indicators to be less uncertain than more response oriented indicators. This has lead us to define *an extended set of indicators* consisting of several sub-sets of indicators, see figure 2.

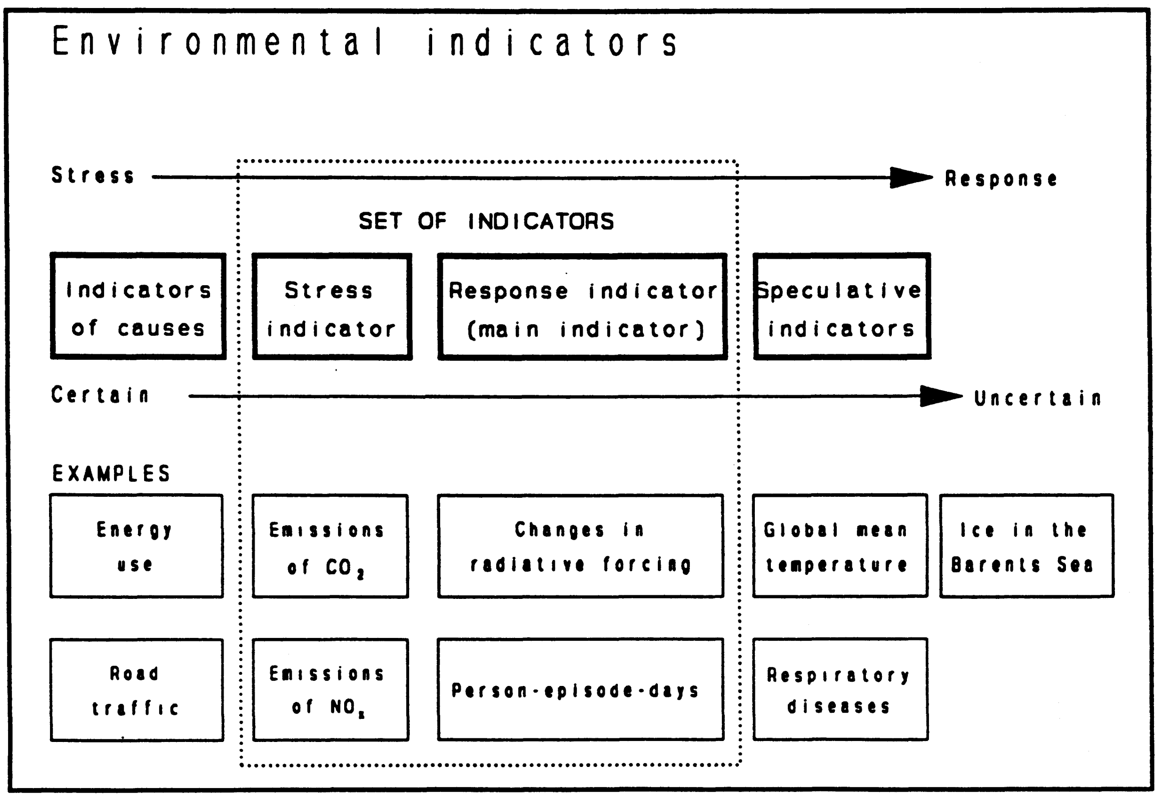

Figure 2 The structure of the extended set of indicators

The main indicator set, described in detail the next sub-section, is primarily aimed at describing the *response* of the environment by way of indicators that are fairly reliably linked to the man-made environmental impacts. To the right of this indicator set in figure 2, we have opened up the possibility for a more speculative indicator set, containing indicators whose linkage to the man-made stresses on the environment at present are not firmly established.

An example is the issue of anthropogenic impact on greenhouse warming. A potential indicator is the change in mean global temperature. However, since there at present is a lack of concensus on the linkage between the observed 0.5 degree centigrade increase over the last century and man-made increase in atmospheric concentrations of greenhouse gases, this indicator is presently relegated to the speculative set of indicators. Instead we have opted for the more reliable indicator of radiative forcing due to increase in the concentration of certain greenhouse gases. Admittedly, it may be argued that this is more of a stress indicator than a response indicator, but the greater degree of certainty associated with this indicator has made us choose this as a candidate for the main indicator set.

To the left of the main indicator set and its more or less speculative companion, figure 2 shows a set of *stress indicators*. With reference to the problem of enhanced greenhouse warming, typical candidates will be the emission and atmospheric concentration of greenhouse gases.

At the far left of figure 2 we have listed an indicator set which we denote *structural indicators*. These are indicators characterizing demographic changes, economic growth and use of environmentally harmful input factors in the economic processes, such as fossil fuels, toxic and long-lived chemicals, etc. The set of information on underlying structures may be important in order to study the causes for changes in stress on the environment. The set of information about underlying structures may be important in order to study the causes for changes in stress on the environment.

Below, we present our choices with regard to indicators belonging to some of the boxes depicted in figure 2. The choices are preliminary and to some extent arbitrary at the moment. Further discussions with experts in various fields may change our opinion. Also the availability of data of reasonable quality may eventually force us to adopt other specific indicators. At this stage the main purpose is to present a viable structure for environmental indicators.

5.1 The response and stress set of indicators

Table 2 gives an overview of the proposed set of main (response) and stress environmental indicators together with some potential environmental indicators. The potential indicators are meant to belong to the main indicator set, but needs to be discussed further. The first column states the environmental effects or problems we are considering. The second and third column shows the corresponding proposed response and stress indicators, respectively. The units of measurement are shown in parenthesis. Below we comment on the choice of each of the indicators in the response (main) indicator set. Preliminary data are presented in the appendices. In the ordinary publication of the indicators, the data will be accompanied by commentaries on the development over time of the indicators, and possibly also compared to similar indicators from other countries.

1. Climatic change
As the main indicator of climatic change, we have chosen changes in *radiative forcing* due to accumulation of greenhouse gases in the atmosphere. Measured at the top of the atmosphere, the Earth receives an energy flux from the sun amounting to on average 1376 Wm^{-2}. In equilibrium the Earth must re-radiate the same amount of energy in order not to heat up or cool down. *Radiative forcing* is a measure of how much of this re-radiated energy is trapped in the atmosphere due to the presence of so-called greenhouse gases in concentrations above pre-industrial levels. In other words, radiative forcing measures the heating effect on the Earth and all its sub-systems from increases in concentration of greenhouse gases after the industrial revolution. The reasons for choosing radiative forcing as an indicator, instead of for instance the more easily understandable change in average global temperature, are twofold. Firstly, the interpretation of changes in global temperature is ambiguous at present. Thus, the temperature may increase for some years without being caused by increased concentrations of greenhouse gases, or it may decrease for a period of time even if a warming effect is in fact present. (Change in mean global temperature is included in the speculative indicator set). Secondly, climatic change may have large impacts on rainfall and number and intensity of storms, while only modest effect on temperature. It may be unfortunate to focus on only one effect, and possibly not the most important one, of climatic change. The choice of changes in radiative forcing as indicator can be seen as a compromise between the aim of choosing a response oriented indicator on the one hand, and the necessity of choosing a reasonable unambiguous indicator on the other hand.

More locally based indicators have also been suggested, such as average temperature in Norway, the southern extension of the ice boundary in the Barents Sea or the height of the tree-limit in Norwegian mountains. In our view these indicators may be strongly affected by local climatic changes not directly related to the global greenhouse effect, and are thus not suitable as indicators for *global* climatic change.

Table 2: The proposed set of main environmental indicators.

Environmental effects	**Main indicators (units)**	**Stress indicators (units)**
1. Climatic change	Radiative forcing (Wm^{-2})	-Atmospheric CO_2 concentration (ppmv). -Global CO_2 emissions (Million metric tonnes)
2. Ozone depletion	Thickness of total ozone column (Per cent change per decade)	-Atm. concentration of gaseous chlorine (pptv). - CFC and halone import to Norway (tonnes)
3. Health	Concentrations above threshold levels (Person* episode-days)	National emissions of SO_2, NO_x, CO, particulates, Pb and NMVOC (tonnes).
4. Noise	Per cent of population reporting being disturbed by traffic noise and noise from construction activities	Traffic volumes (Passenger-km and tonne-km)
5. Eutrophication	Fresh-water lakes classified as polluted (Per cent of total number of lakes)	Discharges of nitrogen and phosphorus to primary recipients (tonnes).
6. Forest damage	Canopy density (Per cent change since last year)	Net import of sulphur and nitrogen to Norway (Per cent of total from different countries)
7. Fish death	Dead fresh-water lakes (Per cent of number of lakes)	
8.Contamination	Thickness of egg shells of predatory birds (µm)	National emissions of Hg, Cd and Dioxins (tonnes)
9-10. Recreation	-Area per inhabitant in urban areas (m^2) - Areas more than 5 km from nearest road (wilderness)(km^2)	Percentage of population in urban ares
11-12. Biodiversity	Disappearance of marine wetland and river deltas (km^2)	
Potential indicators		
13-14. Biological production	Lichen on the Finnmark mountain plateau. Stock of common guillemot.	
15. Marine eutrophication	Biomass of bottom fauna	

2. Ozone depletion.

One of the main reasons for concerns about ozone depletion, is increase in ultra-violet (UV)-radiation at ground level. This will cause an increase in skin cancer and deaths among humans and animals. Thus, UV radiation at ground level is a candidate for an indicator. However, the same sorts of arguments used against mean global temperature as an indicator of man-made climatic change can also be used against this proposal. In addition, for human beings, the changes in life style is probably a much more important cause of skin cancer than the increases in UV-radiation. Still, other animals and plants may be more seriously affected. On the other hand the changes in the ozone layer also indicates changes in the chemistry of the atmosphere. Nobody knows the total effect of these changes. Thus there may be important reasons for concerns about changes in the total ozone column even if the changes in UV-radiation are moderate. This is then chosen as our main indicator. Changes in potential damage from increased UV-radiation is included in the speculative indicator set.

3. Health

The connection between health and pollution is very complex. Simple organisms may react on external stress in predictable manners, but higher organisms will activate defense mechanisms which makes it hard to trace the effects of the external effects. This makes it difficult to establish a connection between health and pollution. On the other hand, pollution has an impact on human health, and the set of indicators would give an incomplete picture of the effects of pollution if the health effects were disregarded. Thus we must, in spite of the uncertainty, try to identify some indicators for the health effects of air pollution.

Two candidates for health-related indicators has been considered. The first was a weighted sum of average concentrations of some important pollutants. This index implicitly requires the relations between doses and responses to be linear. There is little evidence to support this view. Thus, a better indicator is the number of events where the concentration is above some threshold level. We propose to count, for each of the main pollutants (i.e. SO_2, NO_2, CO, Pb, and particulate matter), the number of days when the average concentration is above the 24-hour threshold levels. The observed "episodes" will be weighted by the number of people in the observation area. The unit of measurement will be person*episode-days. The numbers for each pollutant are added together, but in such a manner that the contribution from each pollutant can be identified. A more detailed description of the method and assumptions employed in constructing the indicator is given in the technical appendix.

Admittedly a crude indicator, based as it is on an assumed binary relationship between measured concentration levels and health damage, it is probably the best be can do at present. There are, however, lots of possibilities for improvements of the indicator, some of which we, together with Norwegian Institute for Air Research (NILU), plan to consider in the not too distant future.

4. Noise
The indicator of noise is similar in many respects to the health indicator. Ideally we should use the number of people being affected by noise over a threshold level (e.g. 65 dBA). However, data on this has only recently been elaborated for some major cities, and it is not possible to establish reliable time series now. Instead, we will use data on percentage of population reporting (in interview surveys) being disturbed by noise from different out-door sources, and use this as our indicator of noise.

5. Fresh water eutrophication
Fresh water eutrophication is important for several reasons. Increased input of nutrients will cause increased algal production. The process has consequences for the species composition of both the plant and animal societies, the water quality and bottom conditions. In addition, eutrophicated lakes may become unfit as drinking water, for bathing and lose much of their aesthetical value.

As an indicator we propose percentage of lakes in different state of eutrophication, based on classification of fresh water quality developed by the Norwegian Institute for Water Research (NIVA). The lakes can be weighted by some measure of magnitude, e.g. area covered.

6. Forest damage
Damage to a forest reduces its production potential, and it will also have impacts on the ecosystem in the forest. A damaged forest will in addition lose some of its aesthetical and recreational value.

One perhaps natural choice for indicator is canopy density, and we report on changes in this density from one year to the next. The development in epiphyttical lichen is more sensitive to changes in the environmental stresses, and may be useful as a leading indicator.

7. Fish death
The death of fish in fresh water lakes is generally a signal that we are causing great changes in the ecosystem. Fish in fresh water lakes are also important for recreational reasons. Thus we propose as indicator the number or extent of dead and damaged freshwater lakes. Lakes with an alarming development in evertebrates may be used as a leading indicator.

8. Contamination
The effects of contamination is especially clear in animals at the top of the food chain. High levels of toxic substances in predators are also indicators of contamination at lower levels in the food chain. The lower levels of the chain are also affected indirectly through the impact on the balance of the ecosystem. Contamination also makes fish and game species unfit as food.

The proposed indicator is the thickness of egg shells of predatory birds. The egg shell thickness is influenced by a number of toxic substances, and is thus an indicator covering contamination by several substances.

9-10. Recreation
Environmental damage will affect the recreational value of the Norwegian nature. The indicators 5 to 7 also have recreational aspects, but will not be repeated under this heading. The indicators we would have liked to propose under this heading are indicators of available recreational areas focused on two dimensions: the availability of "green" areas in the close neighborhood, and the abundance of wilderness.

Almost everybody in Norway has access to green areas, and even to wilderness within an hour's travel distance, but the availability of local recreation sites is also important. As an indicator of this we would have liked to use data on the number of people living more than 500 m from a "green area" which is generally accessible. However, this kind of data has proved very difficult to obtain. Instead, we have settled for an indicator showing number of people per unit area within urban areas. Unfortunately, data on this is only available for the years 1960 and 1970. Still, by including this indicator in the main indicator set, we hope that adequate resources will be allocated to update this data set in the not too distant future.

A possible definition of wilderness is areas more than 5 km from the nearest road. Maps of Norway where such areas are indicated have been developed for the years 1900, 1940 and 1980.

11-12. Biodiversity
Biodiversity is important for several reasons. An ecosystem with few species will usually be very vulnerable. A variety of different species is also important as a "gene pool" for e.g. future medicines and to ensure sustainable food production. Finally, biodiversity is important if we recognize the importance of maintaining the natural heritage (recognition of the intrinsic value of nature). Unfortunately, diversity is difficult to measure in one or a few indices.

Biodiversity is dependent on the availability of a diverse set of biotopes. Instead of indicating the biodiversity itself, we have chosen to indicate the development in certain threatened types of biotopes in Norway which are particularly productive and normally sustain a wide variety of species. The biotopes considered are:

- marine wetlands,
- large river deltas,
- uncultivated forests.

5.2 Potential indicators

A crucial task in constructing a set of environmental indicators is to decide which problem areas should be included in the set. Most likely some people will find that we have excluded issues that are just as important to them as any of the ones in the main list. To avoid this problem, we would have to include hundreds of indicators, and the set would not be very useful. The problem is further complicated by the fact that any reasonable indicator set will intersect areas of many different professions. Nobody will have expert knowledge of all the relevant fields. Thus to make a final decision on the content of the set of environmental indicators, we have to collect further information and evaluations from several disciplines.

Since there is doubt concerning several of the indicators, we have, at this stage of the process, chosen to present a list of potential indicators in addition to the main list. These are indicators that may be included if we find that they provide important additional information about the state of the environment. We will also have to consider the balance of the total set. A set with many indicators of slightly different aspects of the intrinsic value of nature, and only one indicator of health aspects of pollution, may for example be considered to be biased towards the intrinsic value of nature.

13-14. Biological production

There is no sharp distinction between the development of the environment and of renewable natural resources. Indicators 6 and 7 may be considered as indicators of the state of renewable resources. Still we have tried to restrict the scope of the project by leaving natural resources out, but will return to them at a later stage. However, the border line is ambiguous, and we are in doubt about where to place it.

Two items that will naturally be included with an extension of the scope are the stock of fish in the marine areas, and lichens on the Finnmark mountain plateau. The heavy fisheries of herring and capelin have probably had important impact on the marine ecosystem. Since common guillemot *(Uria aalge)* is feeding mainly on these two fish species, the stock of this bird species could be an indicator of the stock development of herring and capelin.

Lichens on the Finnmark mountain plateau has been heavily grazed upon by reindeer, at the same time as the growth is retarded due to acid rain. These two impacts has lead to a decrease in the stock of lichen. It is not obvious how to classify this problem, as over-taxation of a renewable natural resource or as a pollution problem.

15. Marine eutrophication

Different expert groups disagree about the causes and importance of this problem. Some claim that the stresses caused by human activities accounts for a very small share of the total stress. If this is the case it will be natural to disregard the problem, and to concentrate on areas where man has an influence. On the other hand, billions of NOK are used to reduce discharges of nutrients and to monitor the state of the marine environment. According to the North Sea Declaration, Norway has agreed to reduce the discharges of nutrients to the North Sea by 50 per cent in 1995, with 1985 as base year.

We have decided to leave the problem out until we have more information about the importance and causes of this problem.

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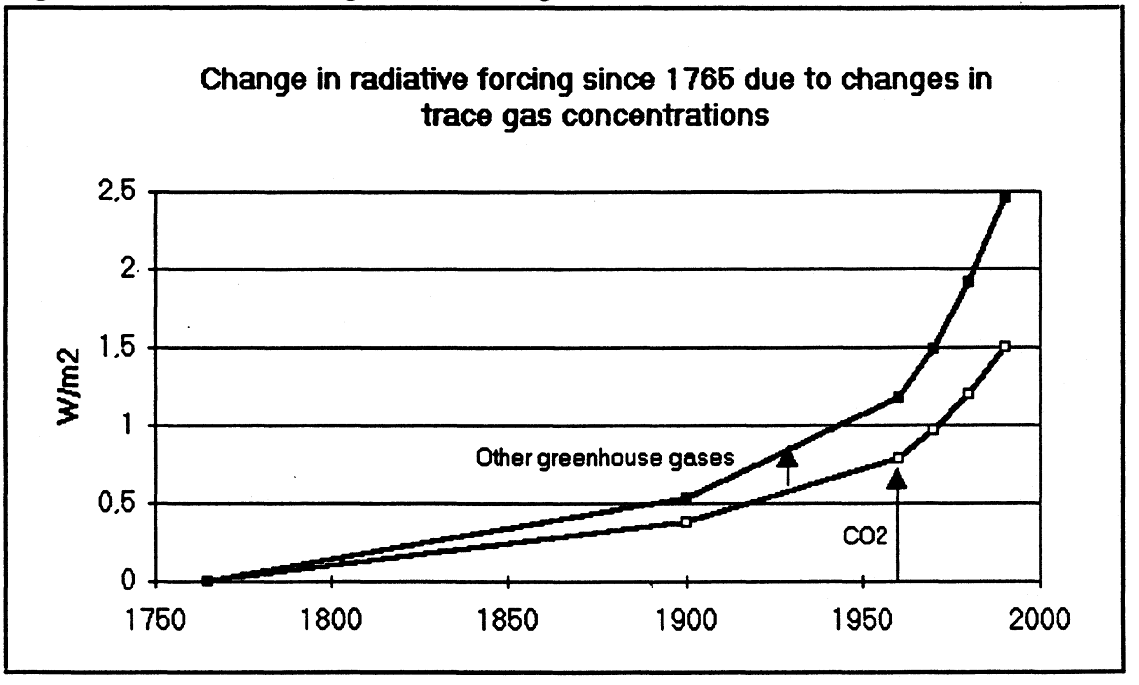
Appendix 1: Environmental indicators and data

Response indicator 1: Climate change

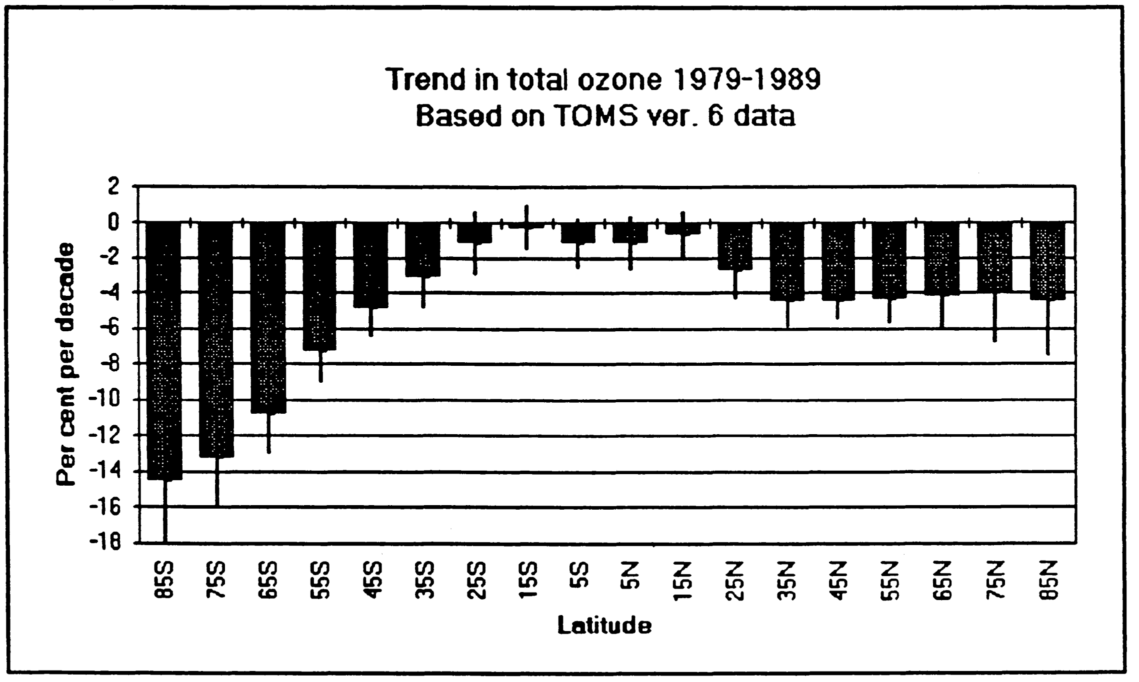
Figure 1 Radiative forcing due to trace gases relative to 1765. Wm^{-2}



Comments: Solar constant = 1376 Wm^{-2}. Solar cycle variability = ∓1,0 W/m^2. Double CO_2 represents +2% increase. Solar cycle variability ∓0,1%

Response indicator 2: Ozone depletion

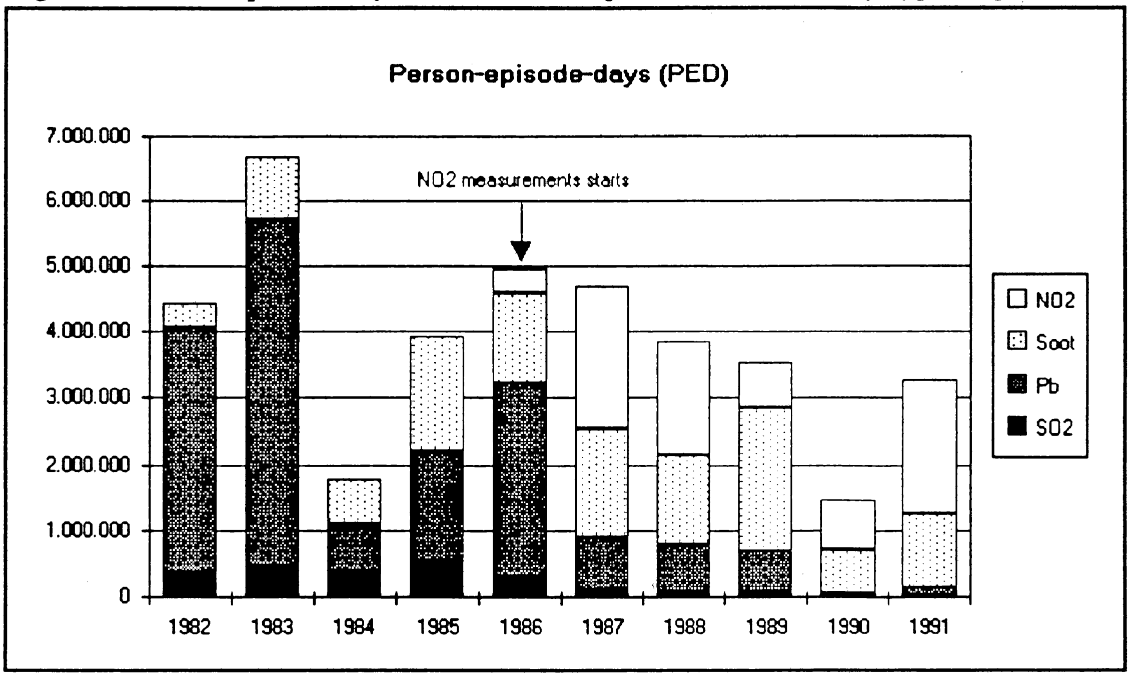
Figure 1 TOMS measurements of ozone depletion over the period 1979-1991. Per cent change per decade. Based on TOMS ver. 6 data



Comments: See speculative indicator no. 2 for translation of ozone data to potential damage to plants, DNA etc.

Response indicator 3: Health effetcs of air pollution

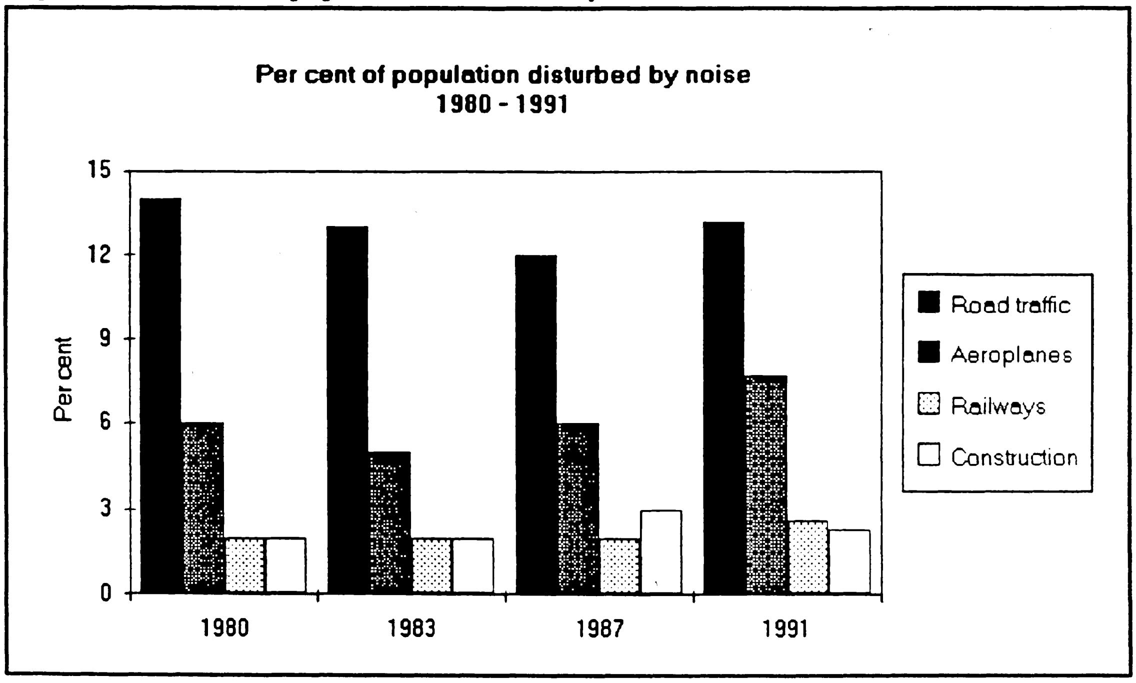
Figure 1 Person-episode-days (PED) for the period 1982-1991 by type of pollutant



Comment: Preliminary data. To be improved by NILU and CBS. See also technical appendix 2 for a detailed description of methodology and assumptions.

Response indicator 4: Noise

Figure 1 Per cent of population disturbed by noise



Comments: Subjective assessment based on interview surveys.

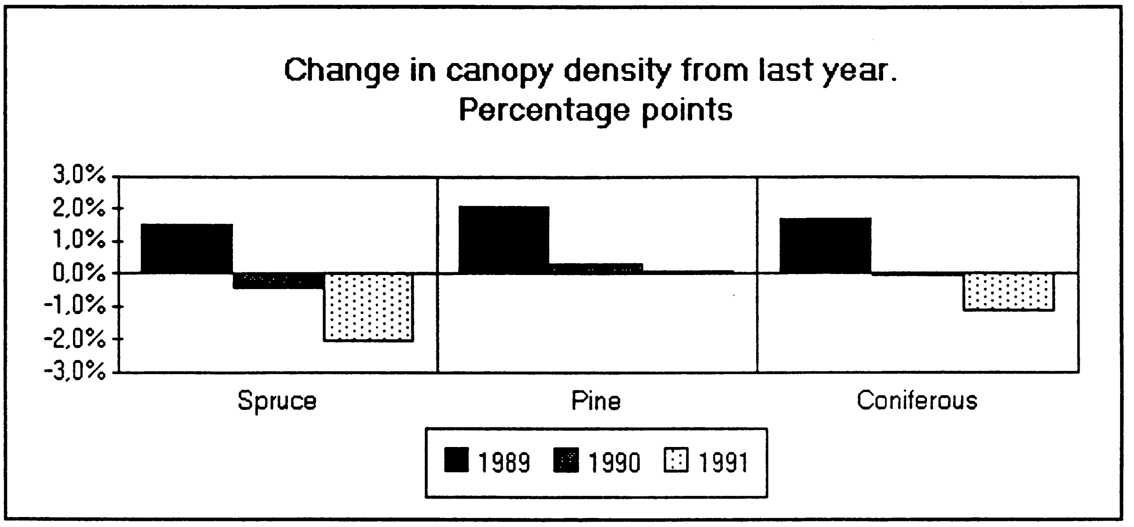
Response indicator 5: Eutrophication

Figure 1

Comment: Data not yet available

Response indicator 6: Forest damage

Figure 1 Canopy density



Comments: Canopy density in 1991 was 82,5 per cent for spruce, 86,1 per cent for pine and 84 per cent for total coniferous forests.

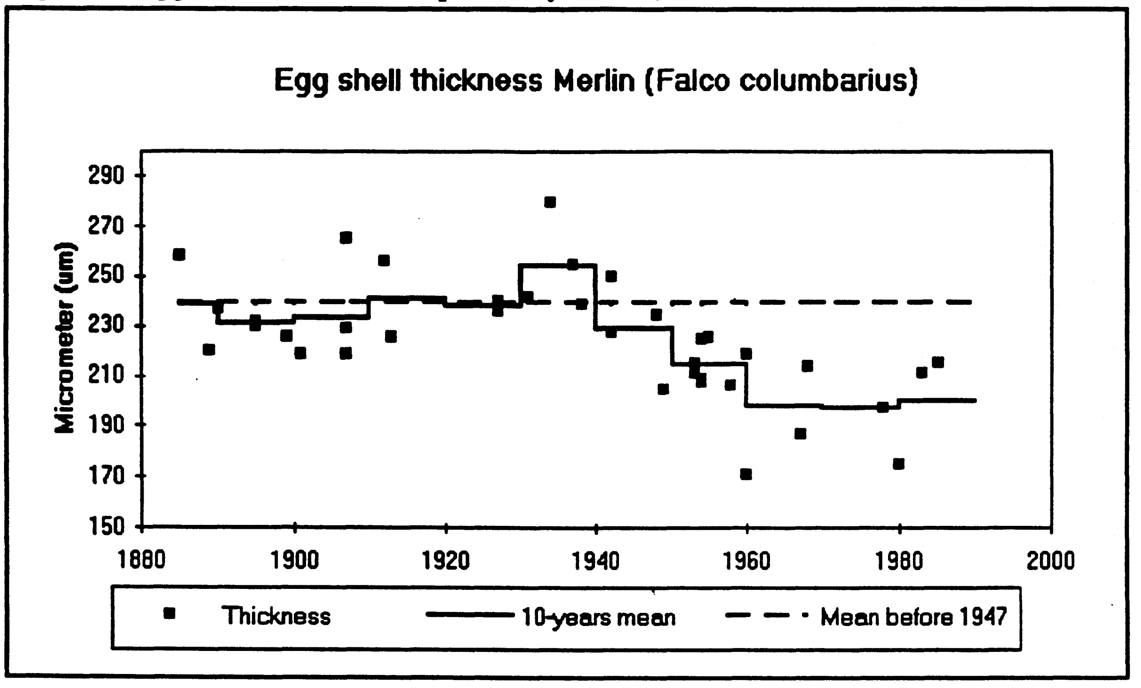
Response indicator 7: Fish death

Figure 1

Comment: Data not yet available

Response indicator 8: Contamination

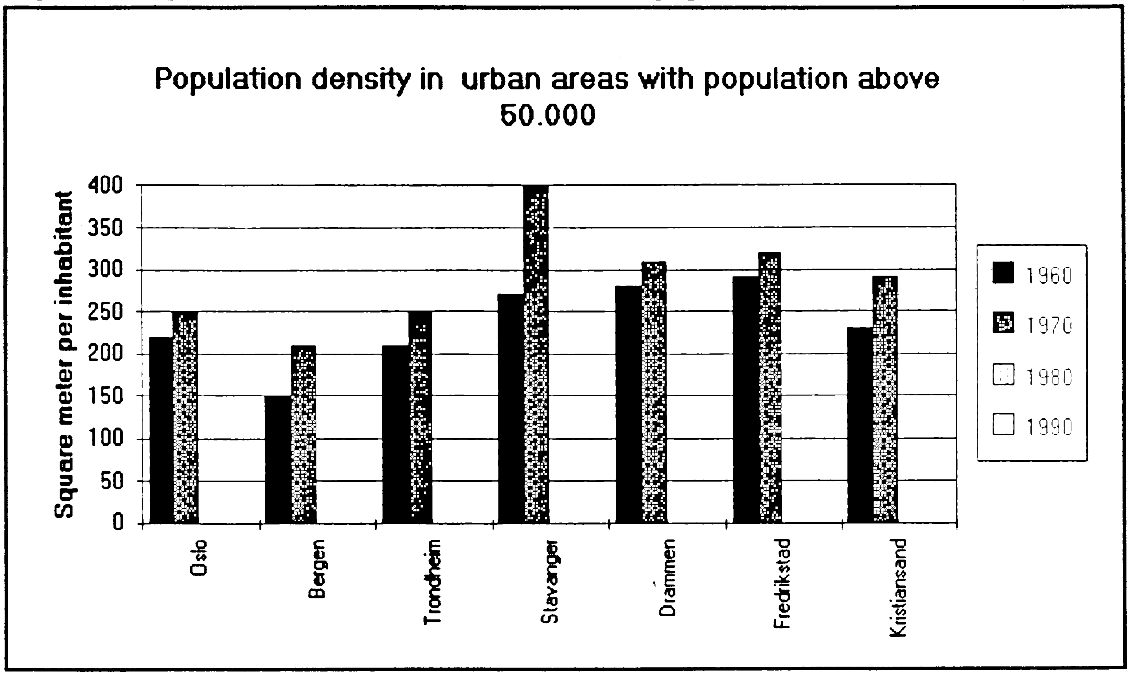
Figure 1 Egg shell thickness of predatory birds (Merlin - *Falco columbarius*)



Comments: Sales of DDT started in 1947.

Response indicator 9: Recreation

Figure 1 Population density in urban areas with population above 50.000

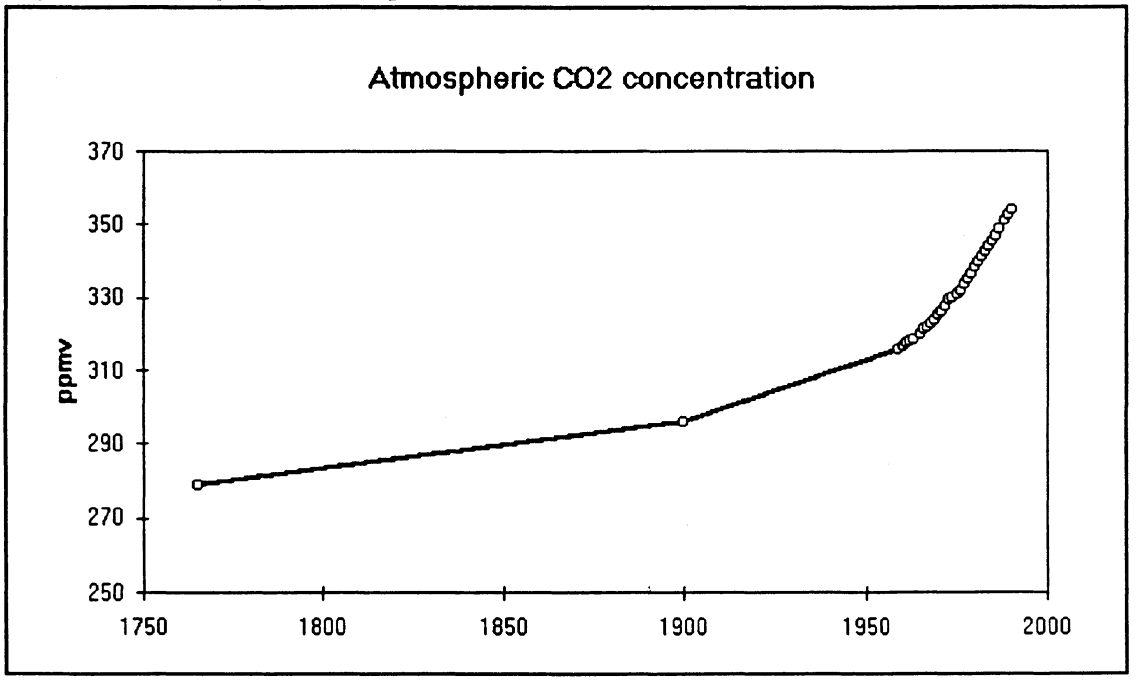


Comments: Data for 1980 and 1990 are under preparation.

Appendix 2: Stress indicators

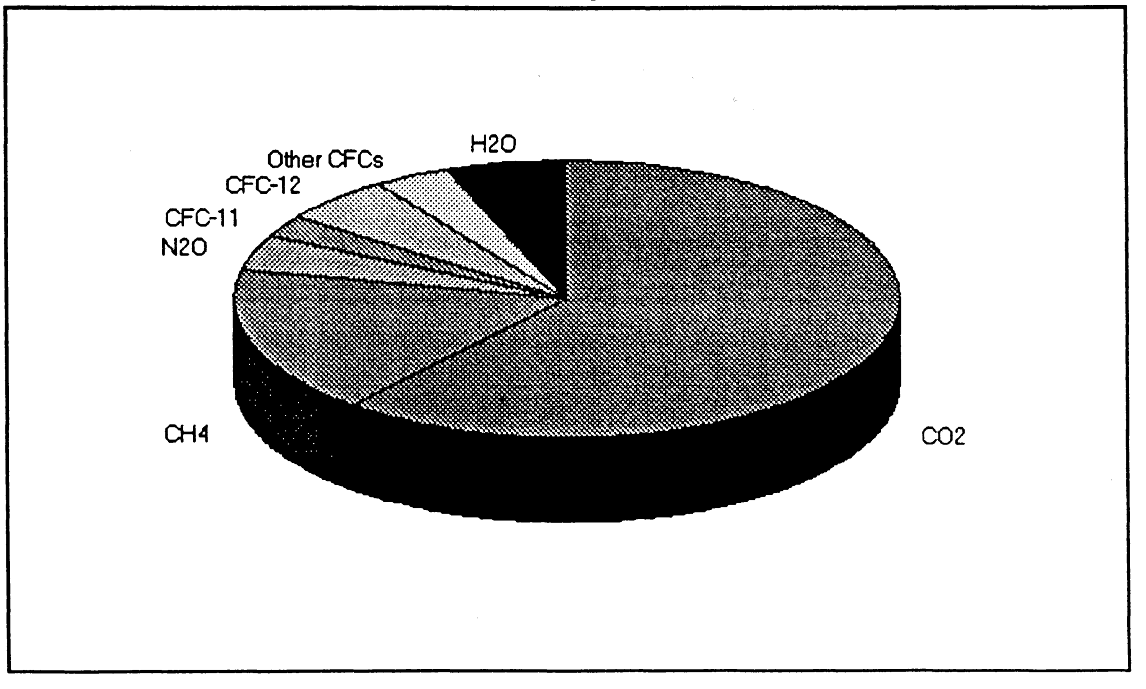
Stress indicators 1: Climate change

Figure 1 Average global CO_2 concentration 1765-1990.



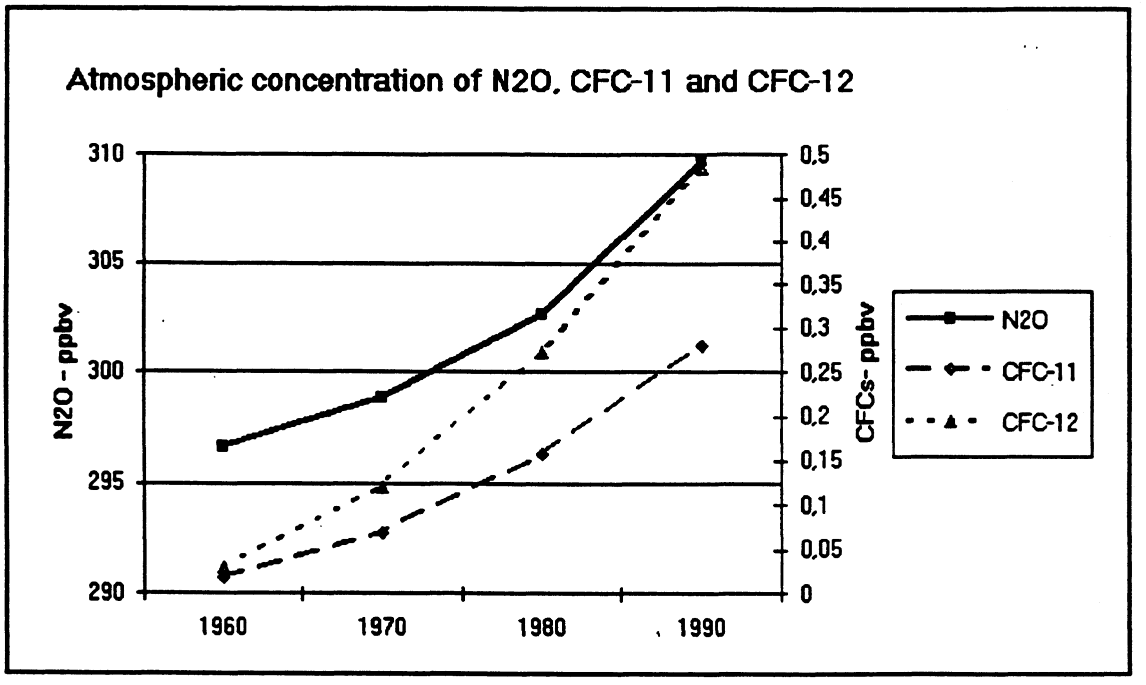
Comments: From 1958: Measured at Mauna Loa, Hawaii.

Figure 2: Contribution from different trace gases to radiative forcing in 1990



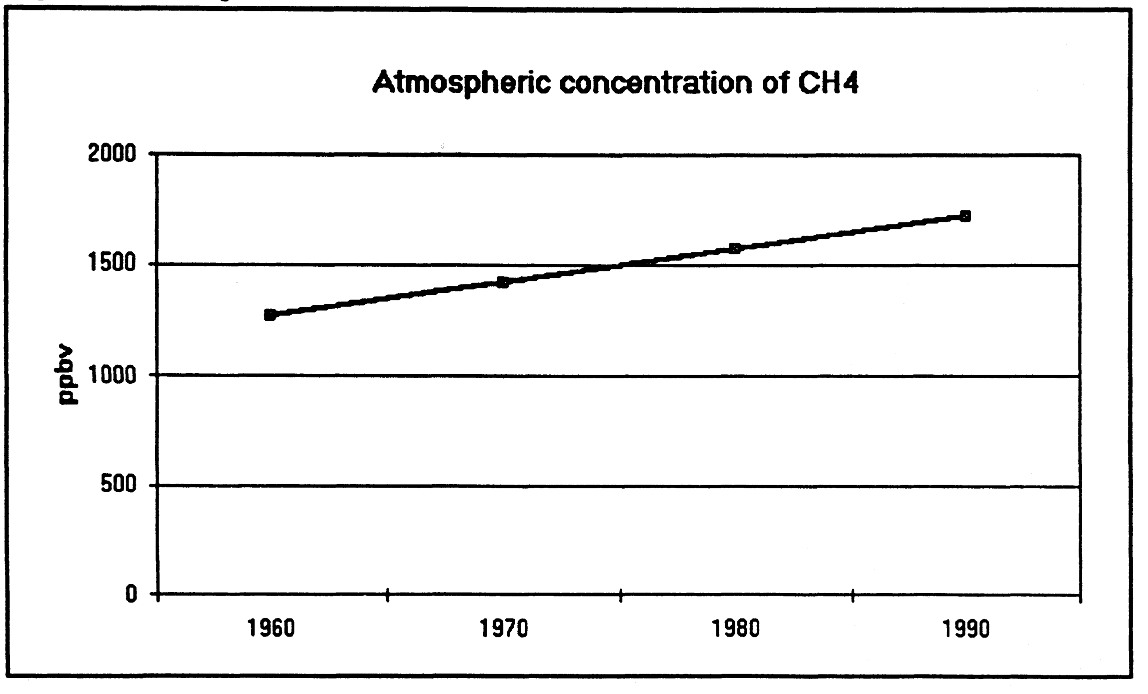
Comment:

Figure 3 Atmospheric concentration of nitrous oxide, CFC-11 and CFC-12 from 1960 to 1990



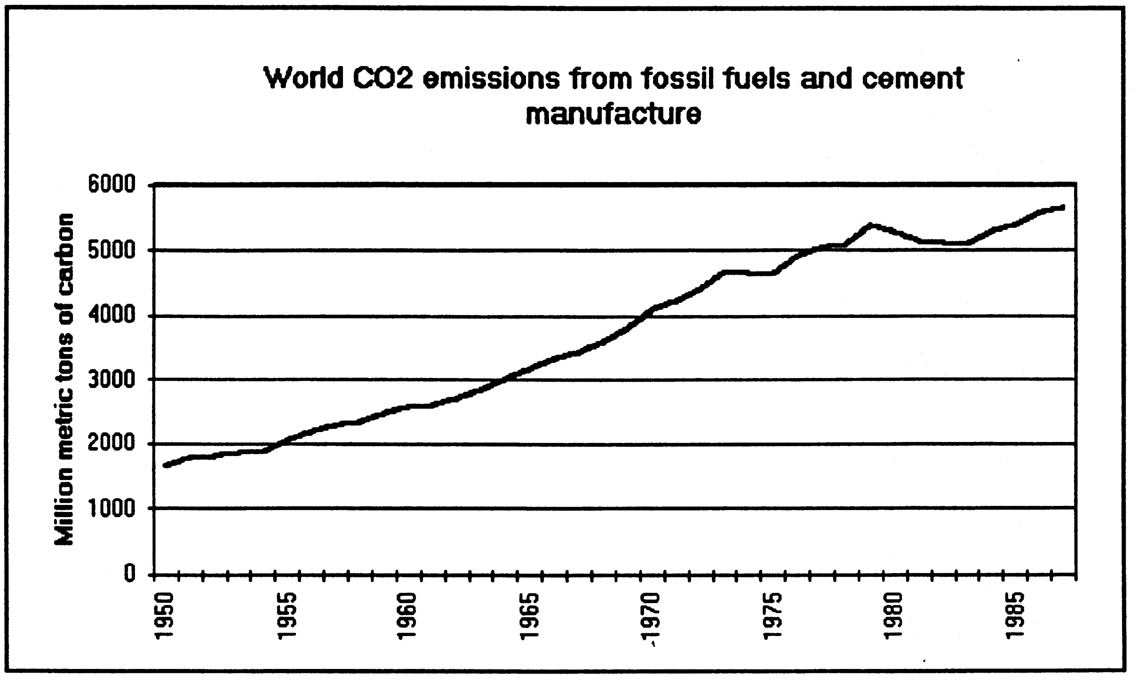
Comments:

Figure 4 Atmospheric concentration of methane from 1960 to 1990



Comments:

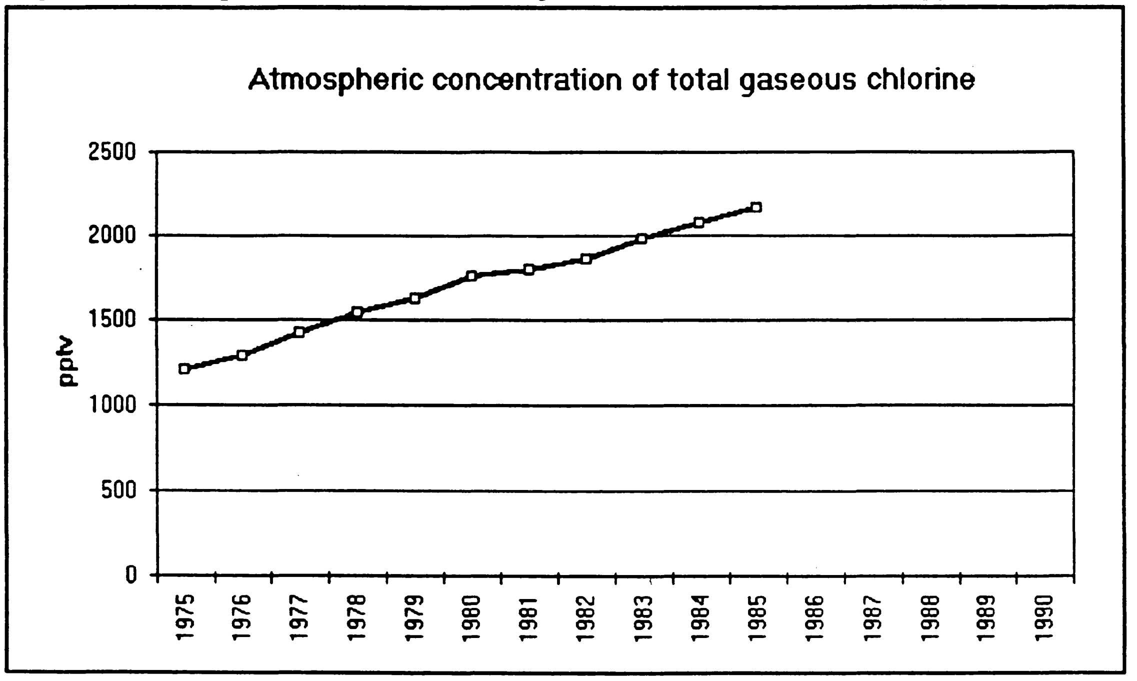
Figure 5 Global CO_2 emissions from fossil fuels and cement manufacture 1950 - 1987



Comment:

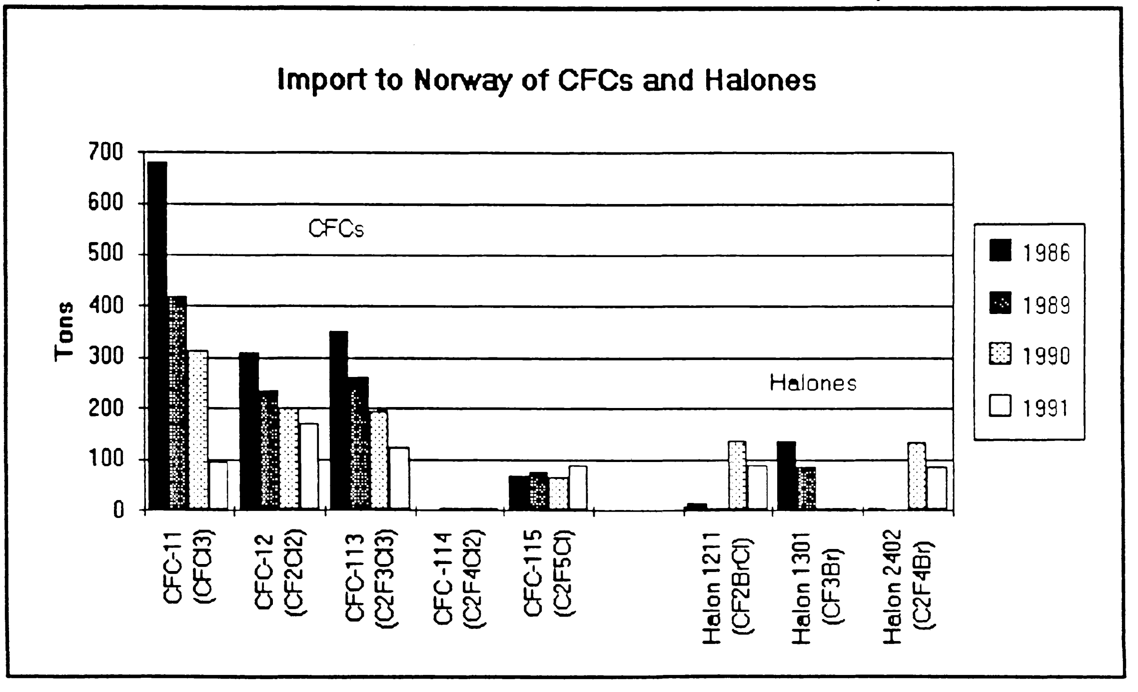
Stress indicator 2: Ozone depletion

Figure 1 Atmospheric concentration of gaseous chlorine 1975-1985. pptv



Comments:

Figure 2 Import of CFCs and Halones as raw materials to Norway



Comments:

Stress indicators 3: Health effects of air pollution

Figure 1 National emissions to air of SO_2

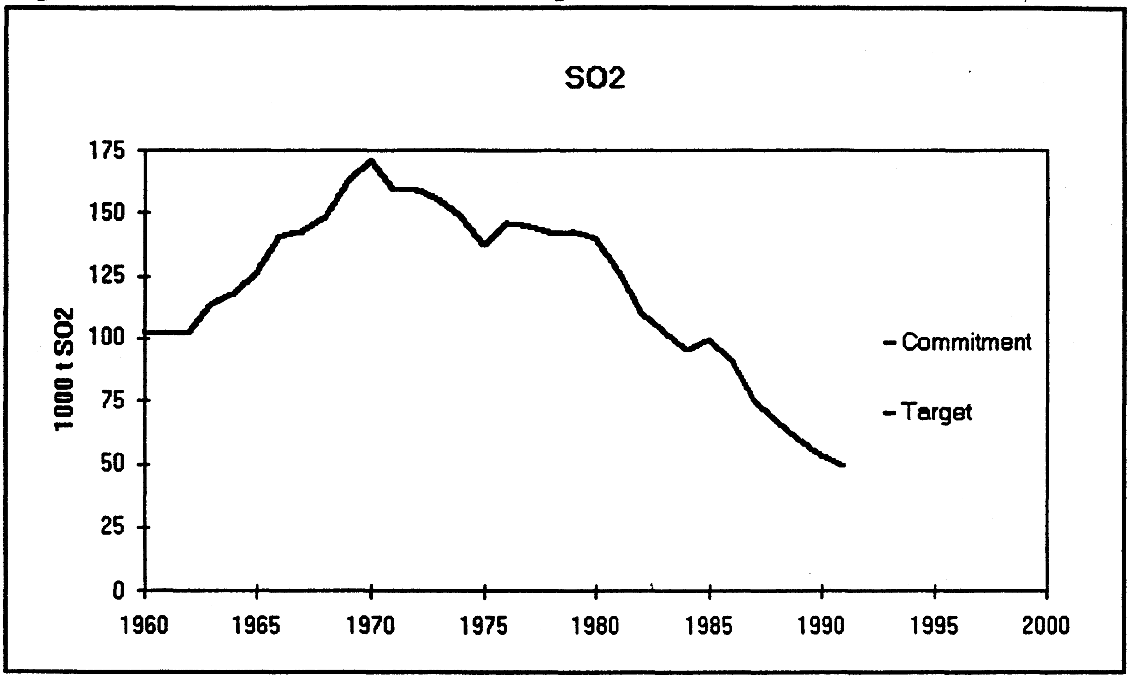


Figure 2 National emissions to air of NO_x

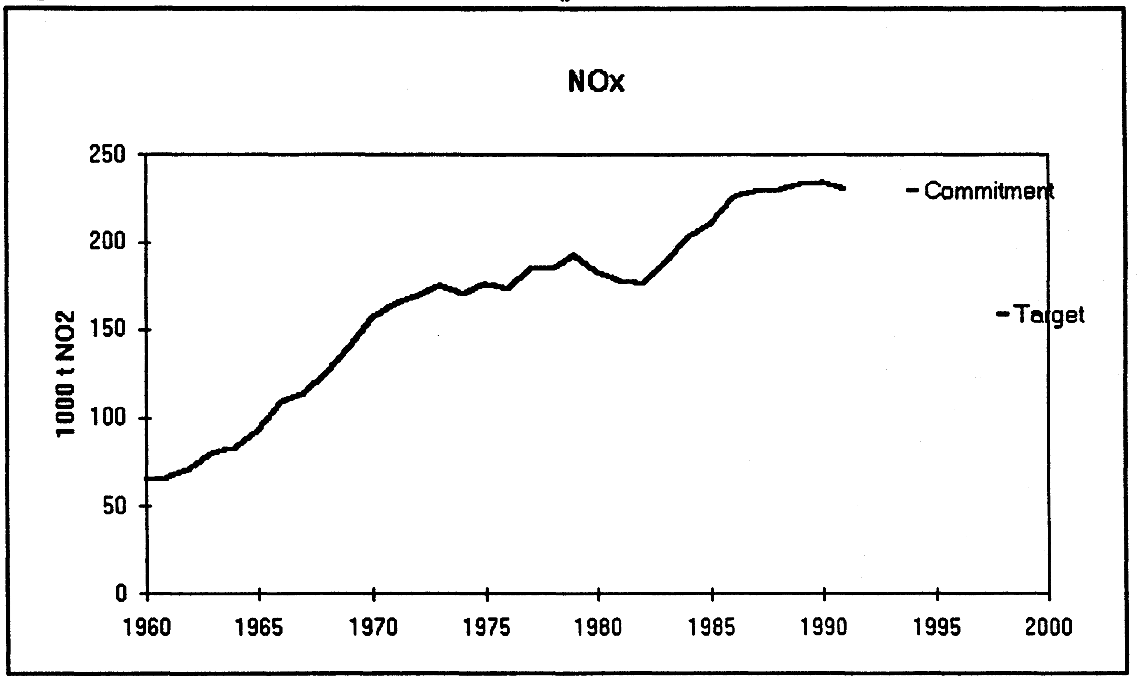


Figure 3 National emissions to air of CO_2

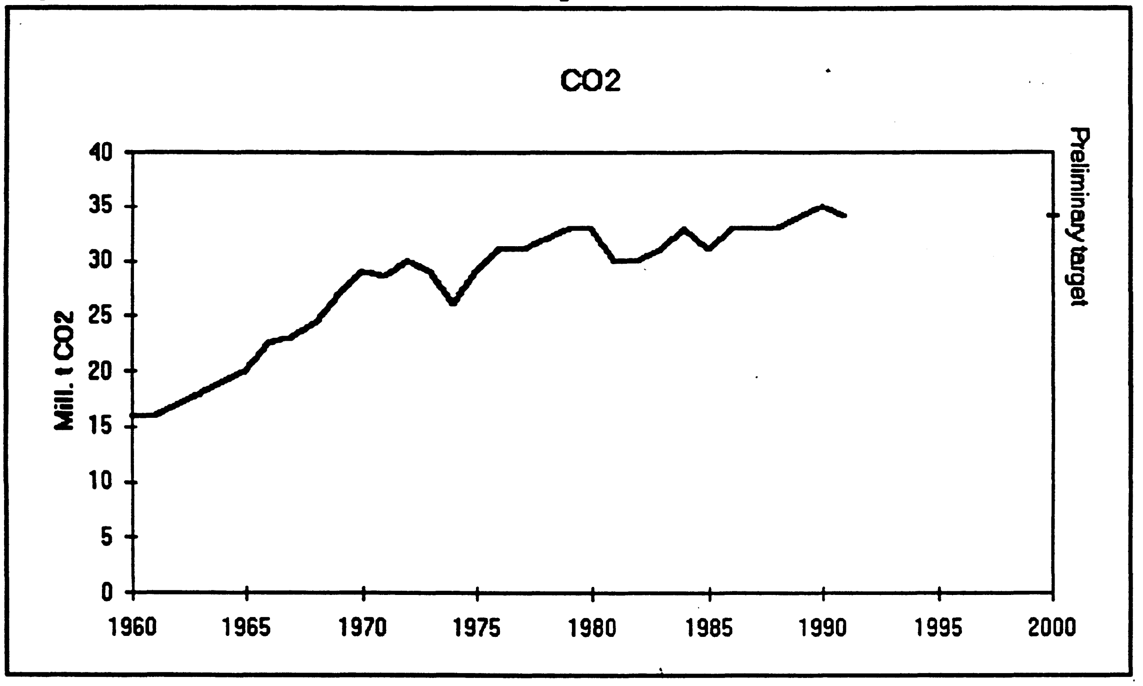


Figure 4 National emissions to air of CO

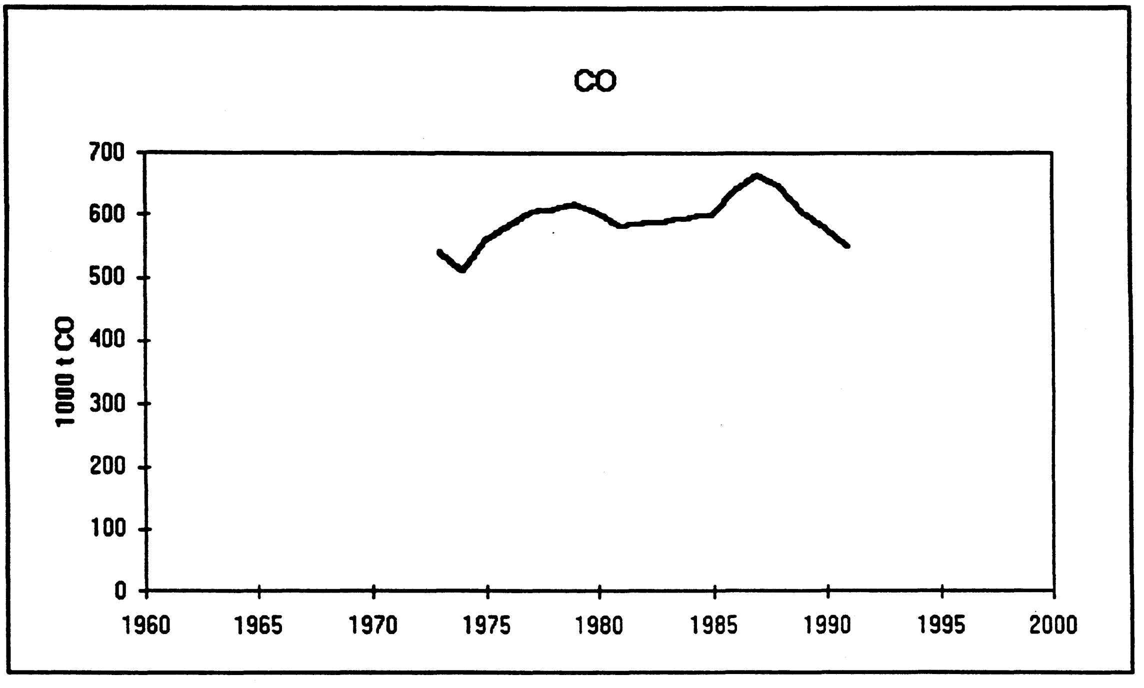


Figure 5 National emissions to air of lead (Pb)

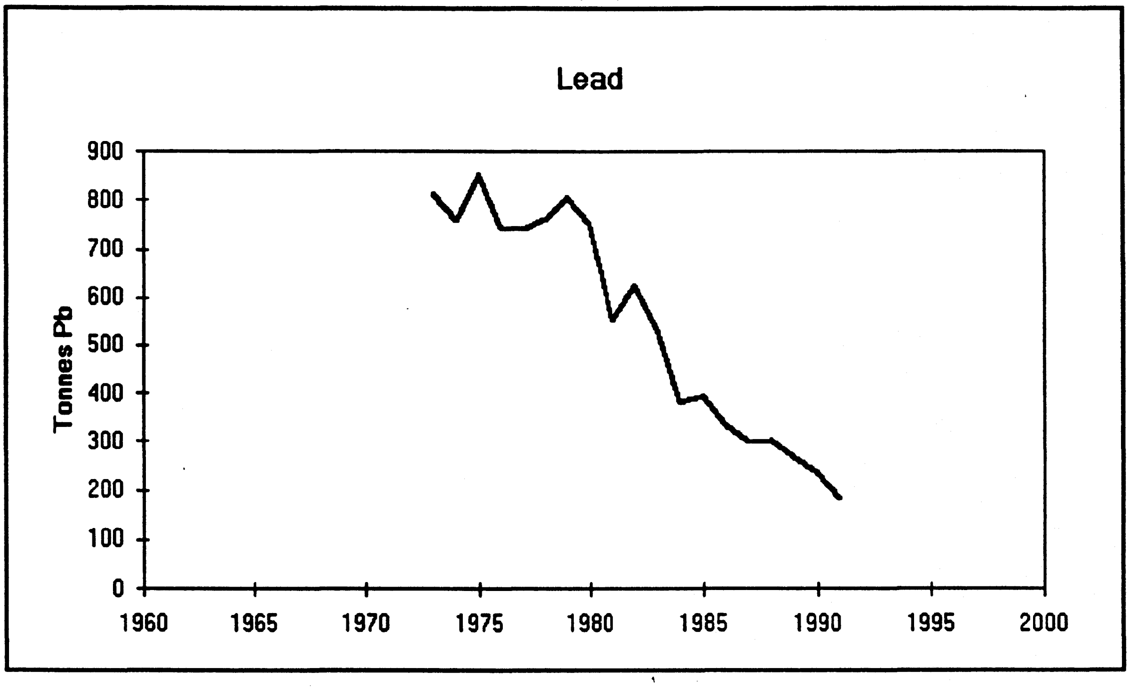


Figure 6 National emissions to air of particulate matter

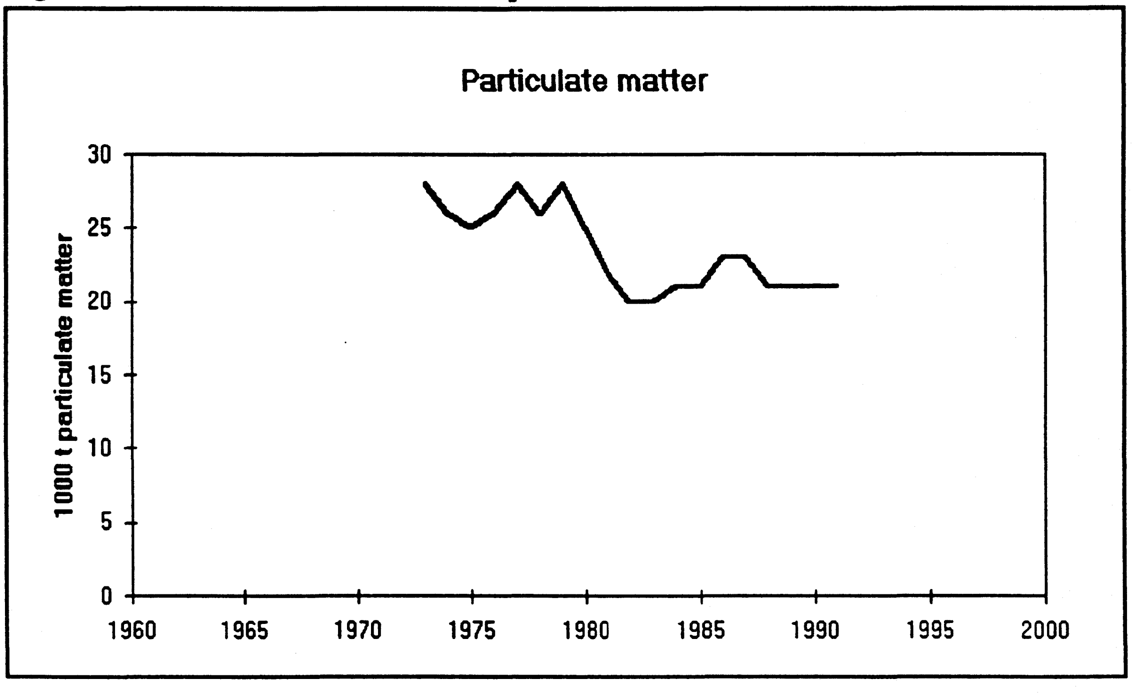
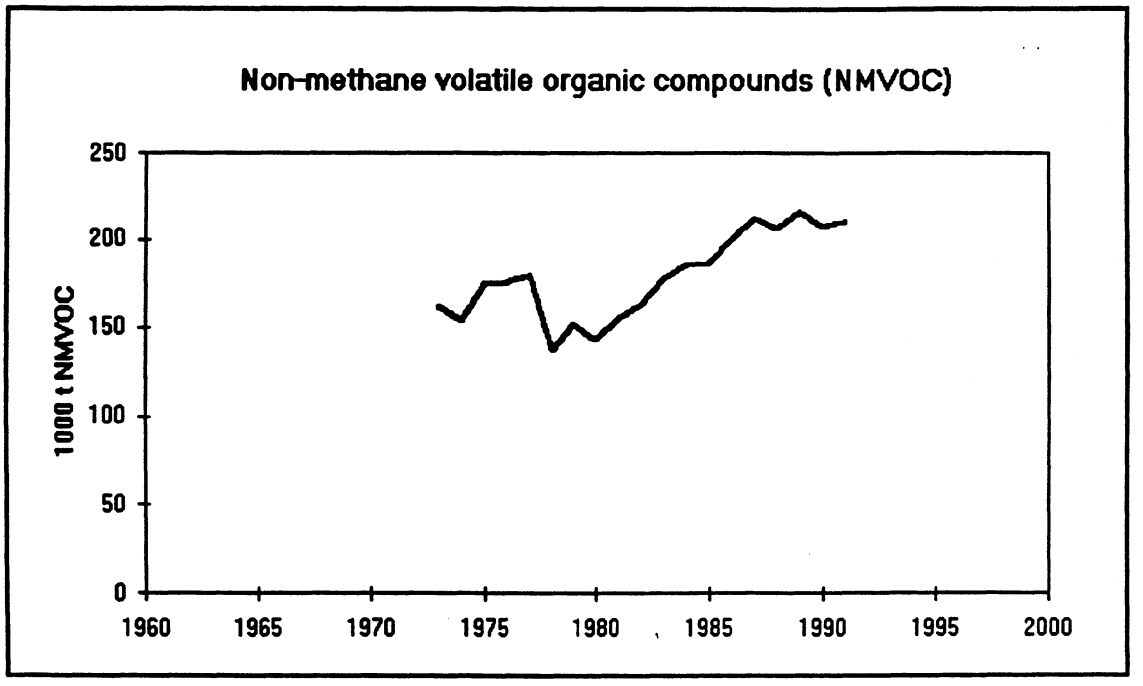


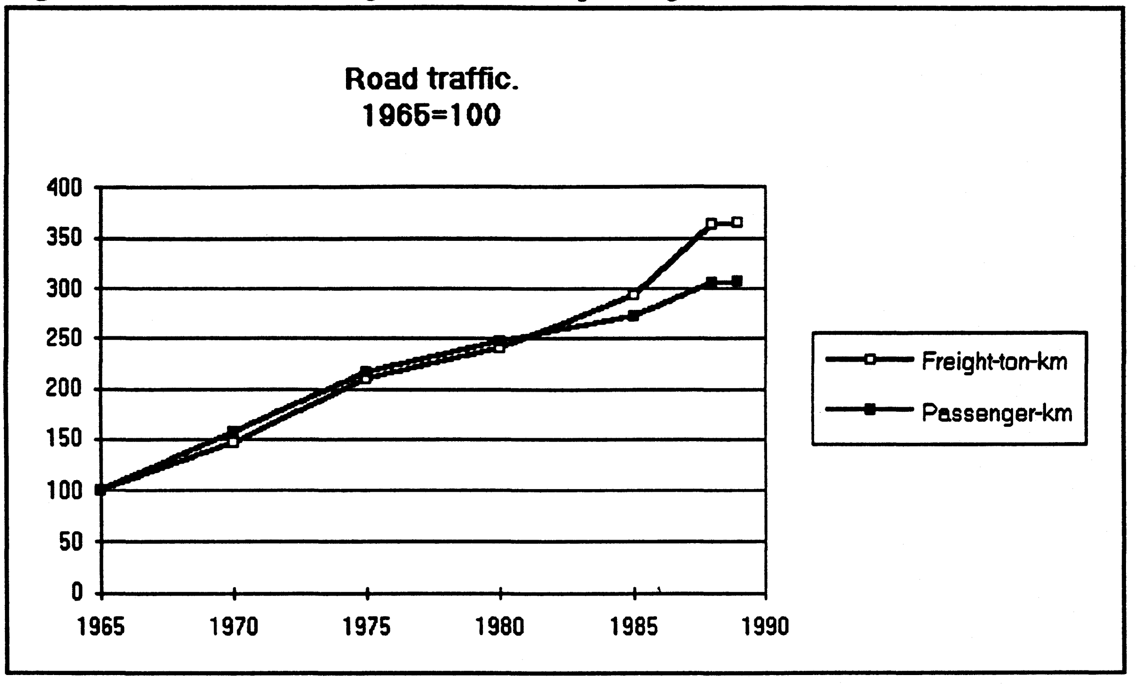
Figure 7 National emissions to air of non-methane volatile organic compounds (NMVOC)



Comments:

Stress indicator 4: Noise

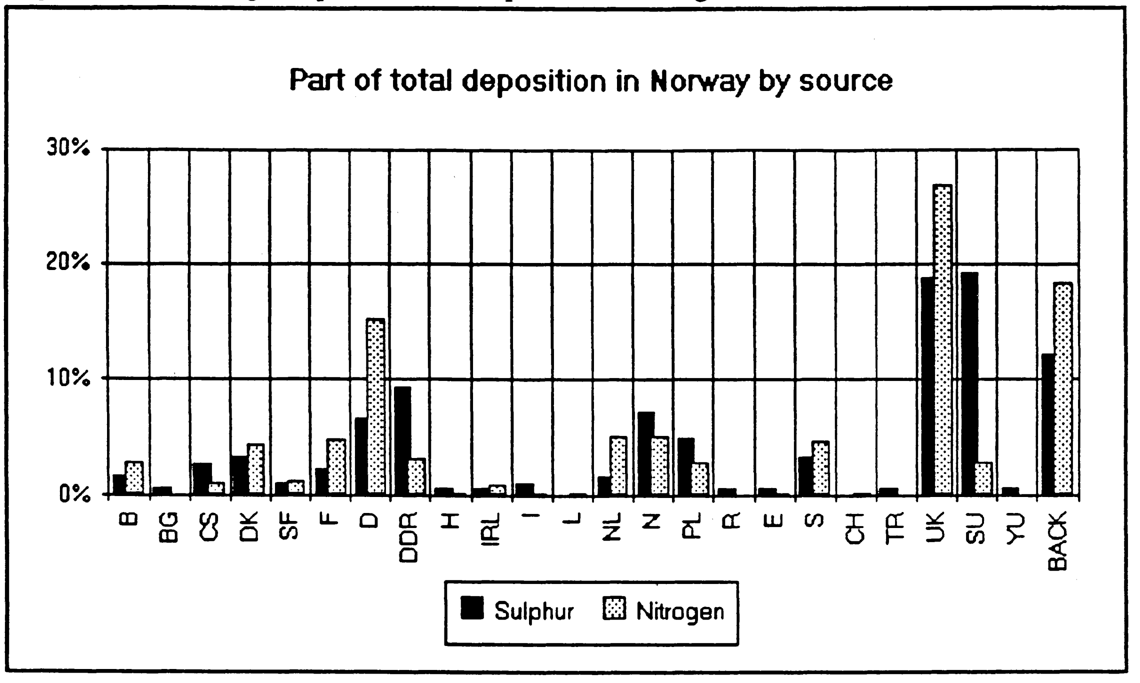
Figure 1 Road traffic. Freight-ton-km and passenger-km 1965-1989



Comments:

Stress indicator 6: Forest damage

Figure 1 Percentage deposition of sulphur and nitrogen from different sources



Comments:

Abbrevations

B	Belgium
BG	Bulgaria
CS	Czechoslovakia
DK	Denmark
SF	Finland
F	France
D	(West) Germany
DDR	(East) Germany
H	Hungary
IRL	Irland
I	Italy
L	Luxemburg
NL	The Netherlands
N	Norway
PL	Poland
R	Romania
E	Spain
S	Sweden
CH	Switzerland
TR	Turkey
UK	Great Britain
SU	Soviet Union (European part)
YU	Yugoslavia
BACK	Background

Figure 2 Contributions to deposition in Norway of oxidized sulphur (measured as S) and nitrogen (measured as N). 1990

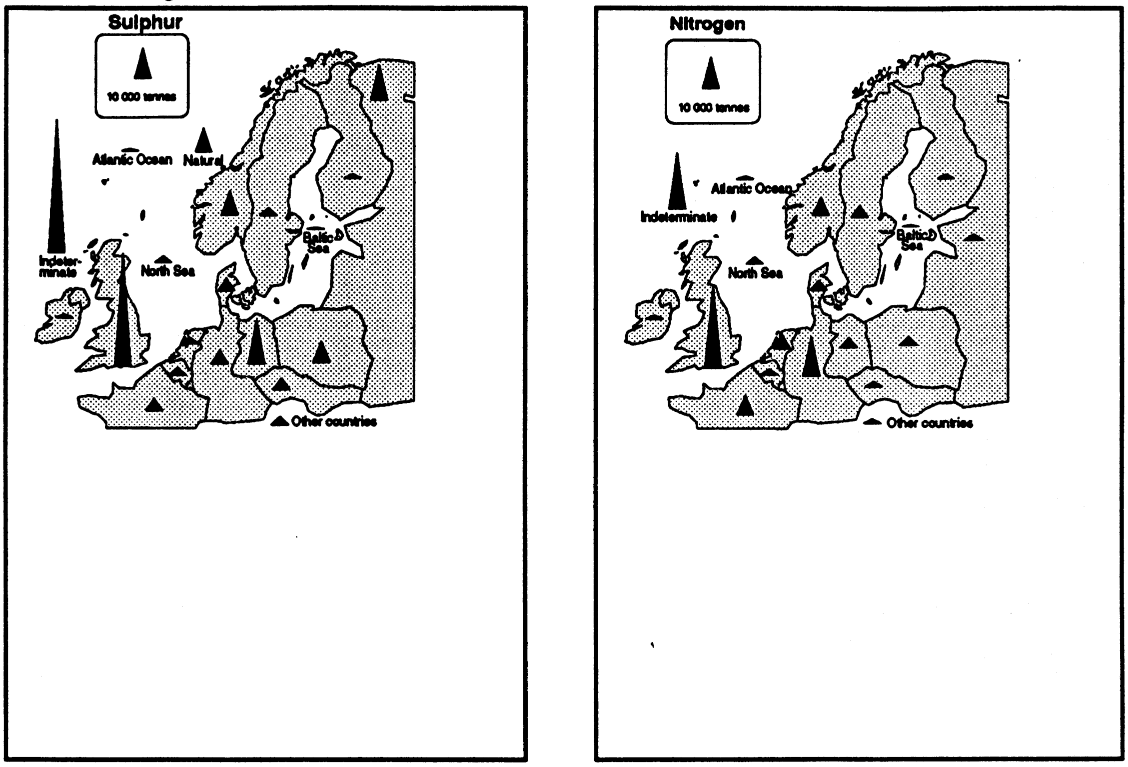
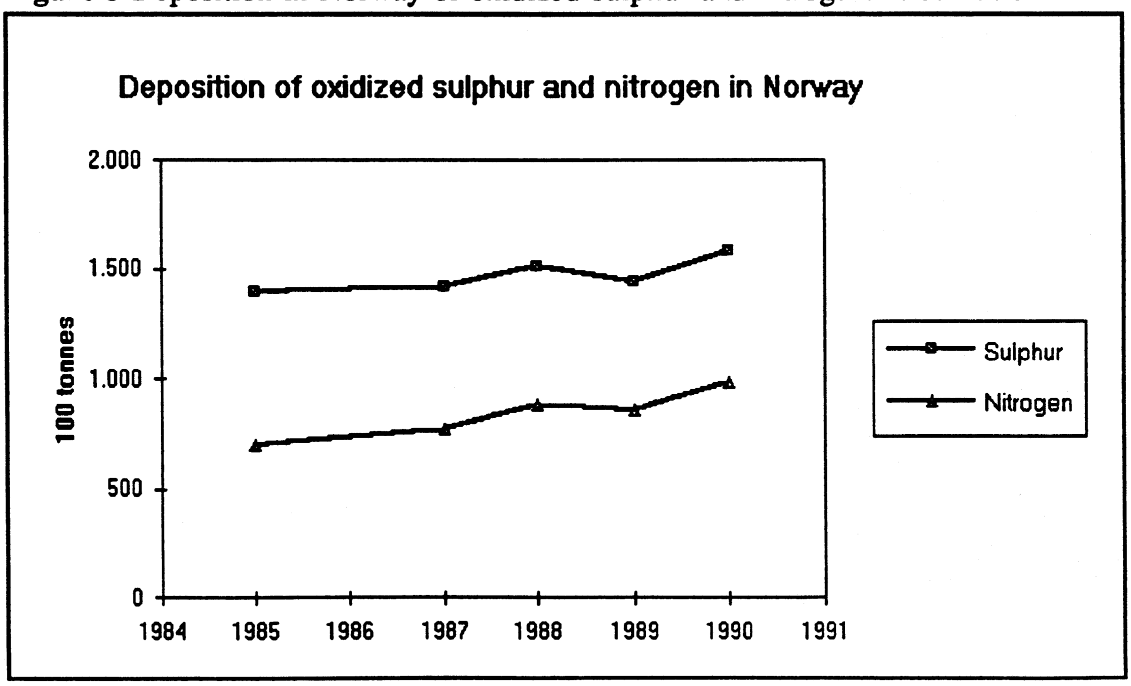


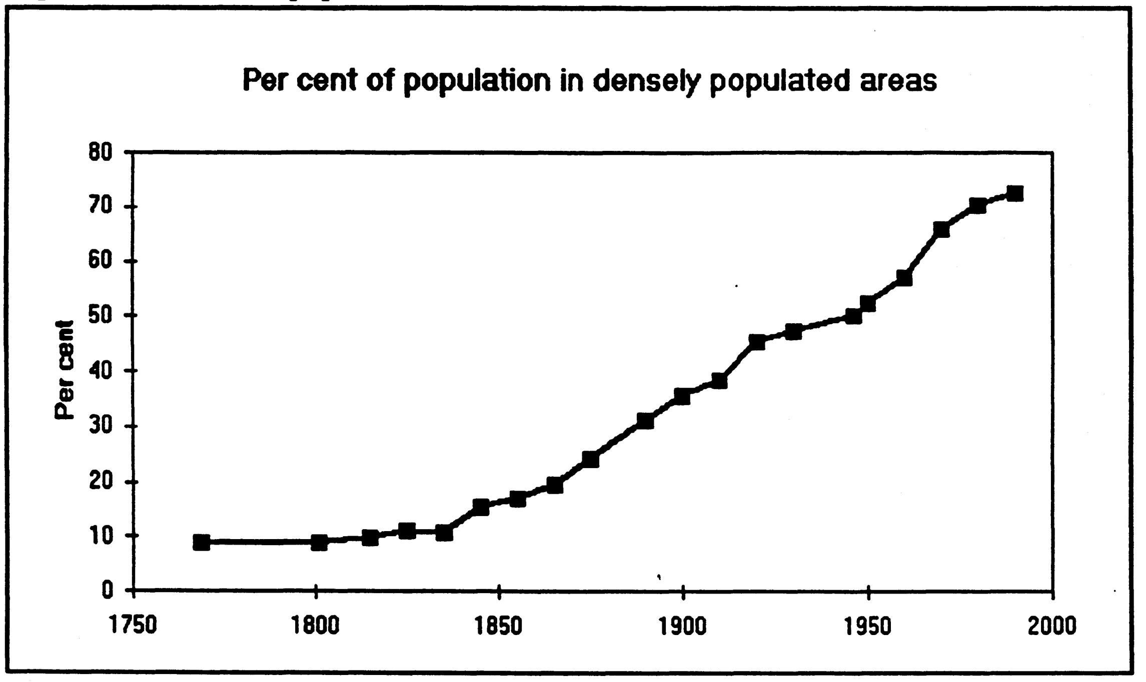
Figure 3 Deposition in Norway of oxidized sulphur and nitrogen. 1987-1990



Comment:

Stress 9: Recreation

Figure 1 Per cent of population in urban areas 1765-1990.

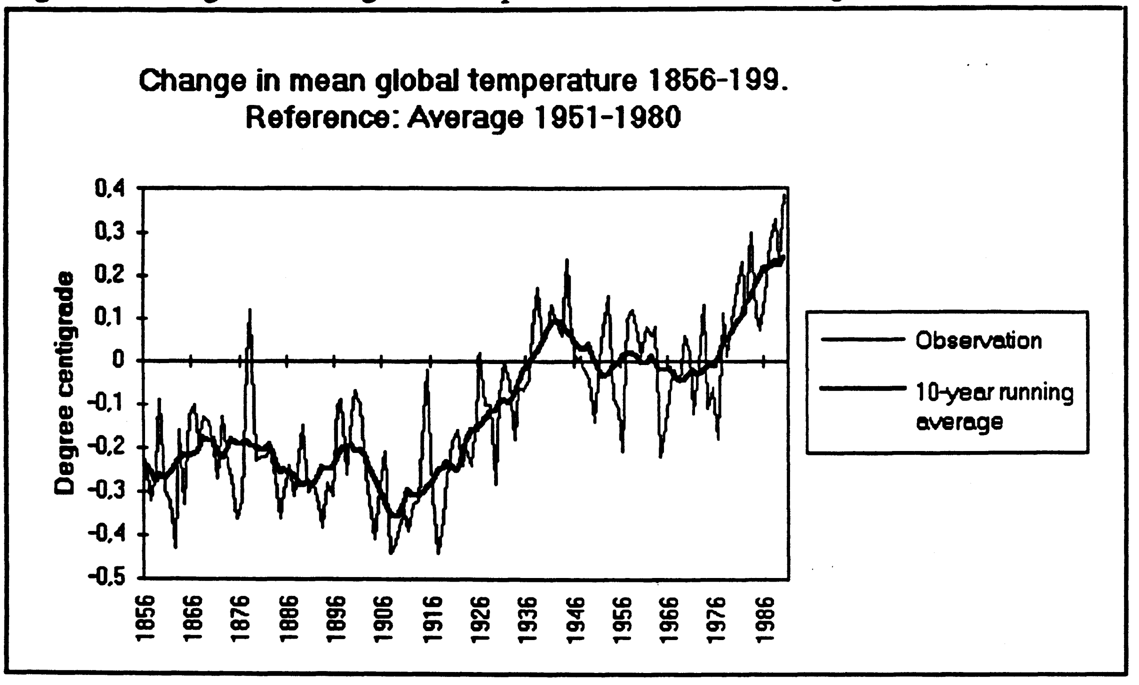


Comments:

Appendix 3: Speculative indicators

Speculative indicator 1: Climatic change

Figure 1 Change in mean global temperature relative to average 1951-1980.



Comments:

Speculative indicator 2: Ozone depletion

Figure 1 Estimated UV damage to DNA due to depletion of the ozone layer. 1979-1989

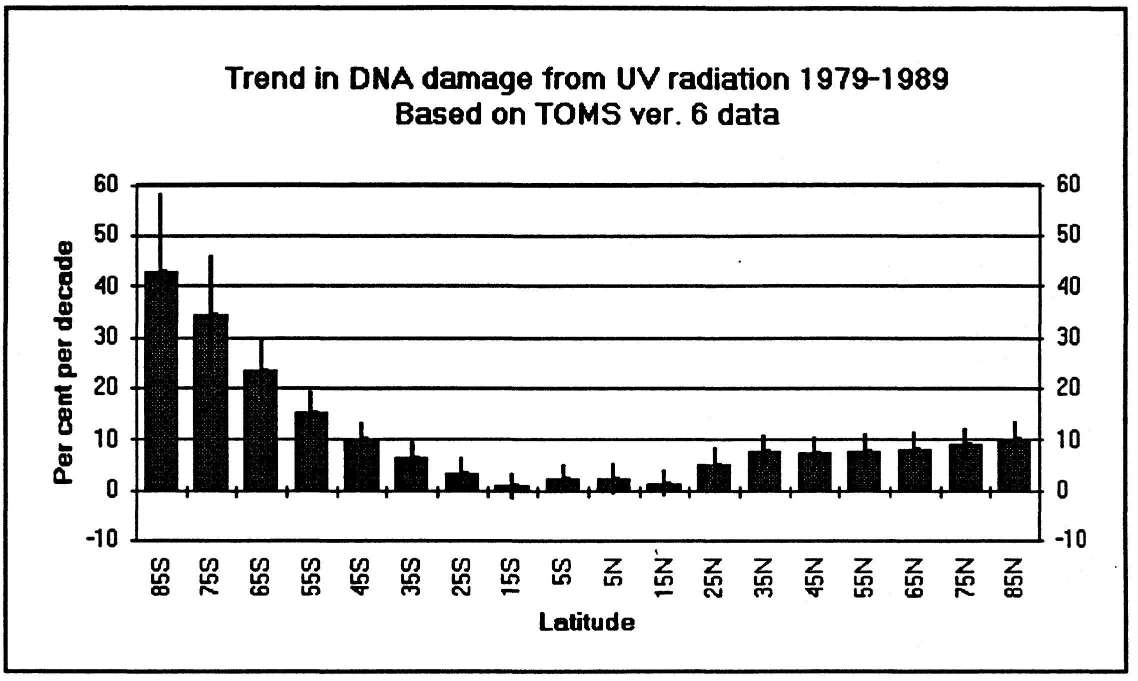


Figure 2 Estimated UV damage to plants due to depletion of the ozone layer. 1979-1989

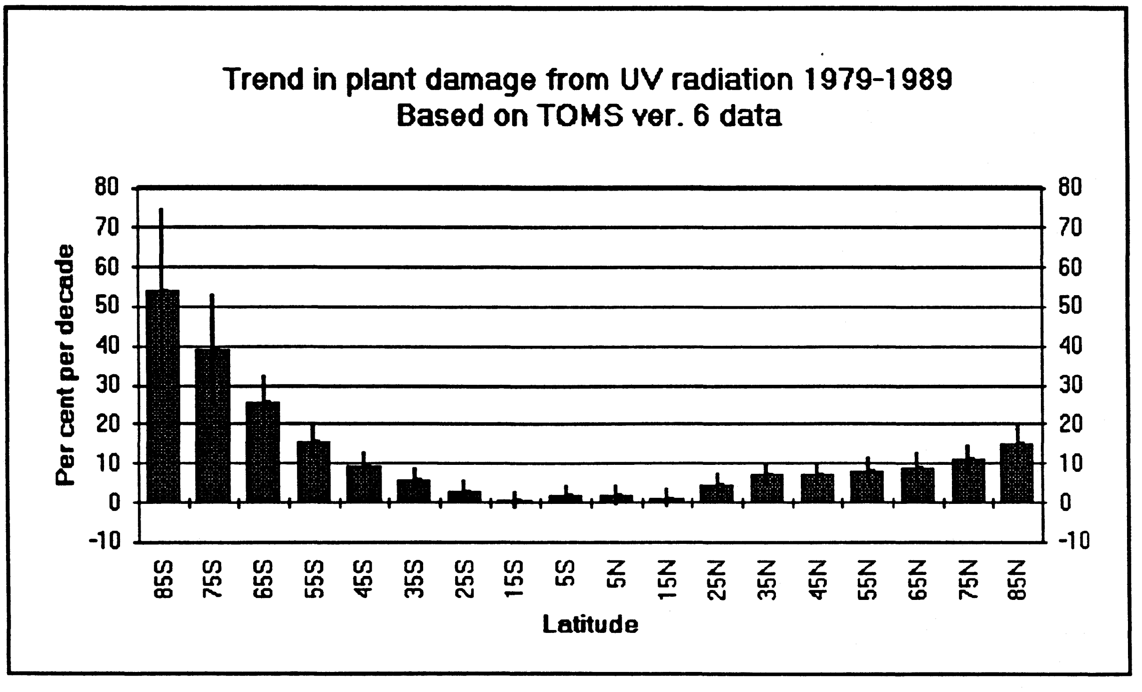
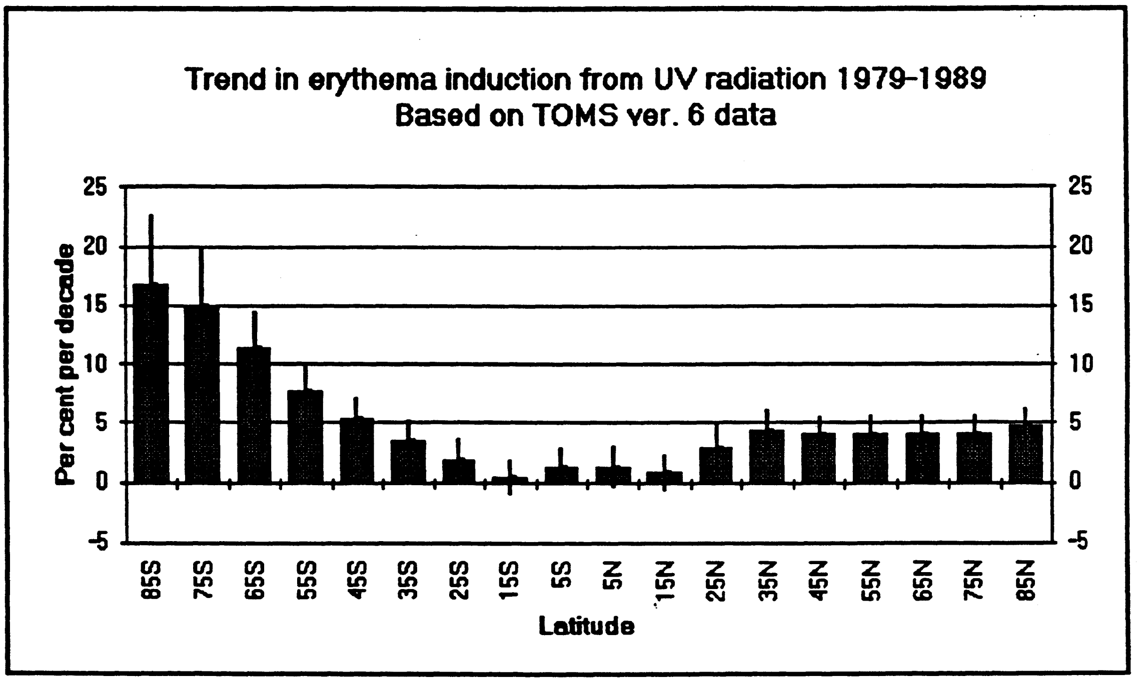


Figure 3 Estimated UV damage to skin due to depletion of the ozone layer. 1979-1989



Comments:

Speculative indicator 3: Health related effects of air pollution

Figure 1 Trends in deaths per 100 000 due to heart failure and cancer

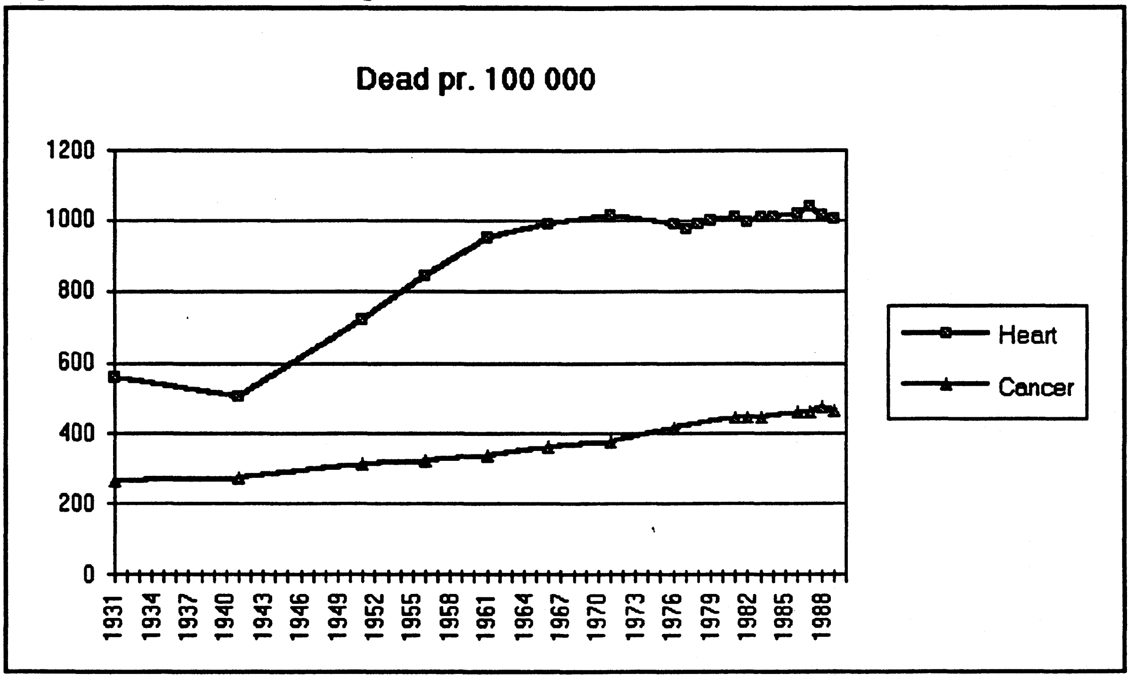
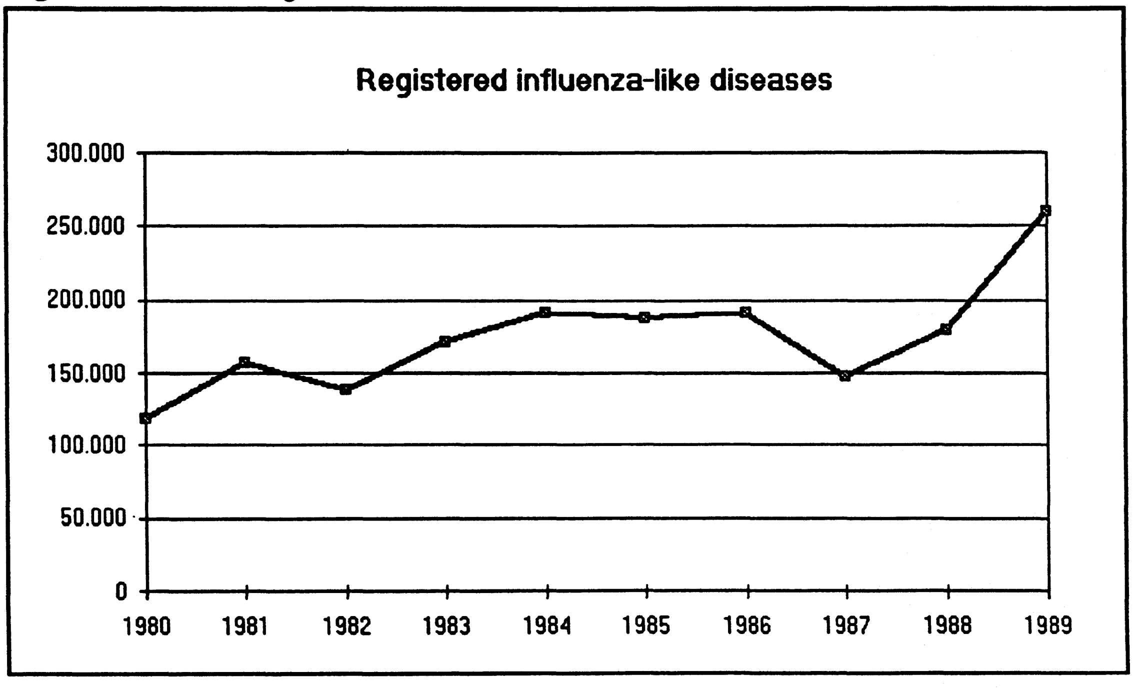


Figure 2 Trend in registered influenza-like diseases



Technical appendix

Data sources

Indicator	Sources	
	Response	**Stress**
1. Climatic change	Intergovernmental Panel on Climate Change (IPCC) (1990): Climate Change. The IPCC Scientific Assessment. Tables 2.5 and 2.6. Eds.: J. T. Houghton, G. J. Jenkins and J. J. Ephraums. Cambridge University Press. Cambridge.	IIPCC (1990): Climate Change. The IPCC Scientific Assessment. Tables 2.5 and 2.6. Eds.: J. T. Houghton, G. J. Jenkins and J. J. Ephraums. Cambridge University Press. Cambridge. World Resources Institute (1990): World Resources 1990-1991. Table 24.4. Oxford University Press. New York, Oxford.
2. Ozone depletion	Scientific assessment of ozone depletion: 1991. Preprint 17. December, 1991. Co-chairmen: Robert T. Watson, NASA, Daniel L. Albritton, NOAA. Madronich, Sasha (1992): Implications of recent total atmospheric ozone measurements for biologically active utlraviolet radiation reaching the Earth's surface, Geophysical Research Letters, Vol. 19(1),pp 37-40 (Table 2)	World Resources Institute (1990): World Resources 1990-1991. Oxford University Press, New York, Oxford. Table 24.3 State Pollution Control Authority (SFT)
3. Health effects of air pollution	Norwegian institute for air research (NILU), Central Bureau of Statistics (CBS).	CBS
4. Noise	Surveys on living conditions, CBS	Car and road statistics, CBS
5. Eutrophication	State Pollution Control Authority (SFT)	SFT
6. Forest damage	NIJOS	- EMEP/MSC-W Report 1/91 The Norwegian Meteorological Institute, Technical report no. 91 (T. Iversen, N. E. Halvorsen, S. Mylona, H. Sandnes (1991): Calculated budgets for airborne acidfying components in Europe, 1985, 1987, 1988, 1989 and 1990.
7. Fish death	Directorate for Nature Research (DN)	
8. Contamination	Nygård (1990), Norwegian Institute for Nature Research (NINA)	
9-10. Recreation	Statistical yearbook 1991, CBS	Statistical yearbook 1991, Population censuses, CBS
11-12. Biodiversity	Directorate for Nature Research (DN)	

A health-related indicator

The health-related indicator is meant to capture some of the health effects that can occur from exposure to air pollution. While it is generally recognized that air pollution can cause damage to health, it is presently very difficult to quantify the damage functions, i.e. to describe precisely what sort of damage that are inflicted due to exposure to specific types of pollutants at different concentration levels. Nevertheless, health authorities in many countries and international organizations have put forward recommendations for threshold levels below which damage to health are not expected to occur. The current recommended threshold levels and guidelines in Norway are listed in table A.1. The levels are given by a lower and upper limit.

Table A.1. Recommended threshold levels for air pollution in Norway. Mean 24-hour average. µg/m³.

	Lower	Upper	
SO_2	100	150	24-h average
NO_2	100	150	24-h average
Soot	100	150	24-h average
O_3[1]	150	200	Hourly value
Pb[1]	1,5	3,0	24-h average

[1] Guideline only.

We have chosen to take the lower levels in this table as our starting point for the health-related indicator for all compounds except ozone. We shall return to the case of ozone below. In the Norwegian system for pollution monitoring, it is registered where and how often during an observation period the threshold levels are exceeded. The registrations have been carried out by the Norwegian Institute for Air Research (NILU) since the late 1970's for most pollution compounds, although the monitoring of NO_2 only has been carried out in the last few years. Also, the recommended threshold levels were adjusted in late 1981.

Monitoring of the different compounds takes place daily, but at irregular intervals. While SO_2 is measured continuously, concentration of soot is only measured daily in the months February, May, August and November. Lead is monitored only in February (previously also in August), while NO_2 is monitored during the winter months October-March, see table A.2.

Table A.2. Monitoring frequencies

Compound	Frequency
SO_2	Monthly
NO_2	October - March
Soot	February, May, August, November
Pb	February[1]

[1] Until 1985, also August

The number of days with registered 24-hour average above the lower threshold level clearly depends on the frequency of observation. In order to normalize the observed so-called *episode-days* (i.e. the number of days where observations exceed the threshold level), we divide the number of observed episode-days with the measurement frequency (i.e. more precisely, we divide the observations with the number of months in a year when monitoring has taken place and multiply by 12). Then, the normalized episode-days obtained in this manner is multiplied by the population in the municipality where the monitoring site is located. We then arrive at what we refer to as *person-episode-days (PED)* for each polluting compound. Finally, we construct the health indicator by adding the PEDs for each compound.

A further problem in constructing the health indicator should be mentioned. The problem is related to the fact that the number of monitoring stations within the survey system has been changing over time. However, the number has been predominantly decreasing, and the decrease has been due to consistent non-observation of episodes at the stations in question. Thus, their deletion from the monitoring network will not affect the indicator. In a few instances stations has been moved within the municipality and a few have also been established during the sampling period. Analysis indicates that this does not pose an important problem for the overall development of the proposed indicator.

Several uncertain assumptions are made in establishing the health-related indicator by using the approach described above. First, each episode-day is weighted equally, whether the measured concentration level is just above the threshold level or very much higher than the threshold level. This is a reflection of our ignorance of the real dose-response relationship. Second, by extrapolating the observed episode-days from the period of observations to the whole year, we implicitly make an assumption that the probability of observing an episode is equal throughout the year. This is clearly a simplifying assumption that is strictly incorrect, since climate conditions has a strong, but largely unknown, influence on the measured concentration levels, and the climate changes very much throughout the year. Also emission levels show clear seasonal variations. And third, by multiplying by the population in the municipality of the monitoring sites, we assume that these population figures represent the number of people actually exposed to high concentration levels. All of these assumptions can be criticized for being unrealistic. We nevertheless hope that the final indicator give some sense to what extent air pollution is a health problem, and that its development over time reflects real changes in one aspect of the state of the environment. Anyhow, it seems to be the best we can achieve today with our limited knowledge of how air pollution affects human health and with the design of the existing monitoring system of air pollution.

For ozone there exists an official definition of what constitutes "an episode" and number of episode days in a year is reported directly. A day is defined as an ozone episode if maximum hourly concentration is above 120 μg/m^3 at several stations simultaneously, or maximum hourly concentration exceeds 200 μg/m^3 at one or more stations. Number of episode days in a given year is reported by NILU. The measuring stations are generally located outside cities and urban areas, as the main contribution to ground level ozone concentration in Norway is due to transboundary pollution and affects mainly the southern part of Norway. The number of episode days are therefore multiplied by the population in the 9 southernmost counties (Østfold, Akershus, Oslo, Buskerud, Vestfold, Telemark, Aust- and Vest-Agder and Rogaland) to arrive at a PED for ozone. However, since the background ozone is destroyed in urban areas due to the presence of for instance particulate matter, we have chosen not to include the ozone PED in the main indicator set.

Below we report by way of 6 figures some preliminary data for the PEDs, and point out some still unresolved problems.

The first figure depicts the observed (i.e. not "normalized") PED for SO_2, disaggregated by monitoring stations with registered observations above the threshold level . The figure shows observations from 1979 and onwards to mid 1991. However, the recommended (lower) threshold level was reduced in 1981. Thus, the somewhat lower level at the start of the depicted period is artificial, since it refers to a more stringent test for a measurement to be characterized as an episode. The low values at the end of the period are however real.

Figure 2 shows the PED for soot. The curve is somewhat more uneven than the one in figure 1, reflecting that measurements are only made every third month. Also the time period covered are shorter than in figure 1.

Figure 3 shows the total observed PED for NO_2. As already mentioned, NO_2-concentrations have only been monitored for a short period, and is only measured during the winter months October to March.

Figure 4 shows the observed total PED for lead (Pb). Also here the observation frequency has varied over the observation period, from initially covering both the months of February and August to only including February in the last few years. Introduction of unleaded gasoline has clearly reduced the abundance of lead.

Figure 5 shows the PED for ozone (O_3), obtained by multiplying observed number of episode days with the population in the southern part of Norway (approximately 2,3 million in 1990). Calculated in this manner, the PED for ozone exceed by orders of magnitude the other PEDs. However, presently we have chosen not to include ozone in our total PED indicator.

Combining the PEDs of the various compounds (excluding ozone) after they have been normalized to annual values, we obtain the response indicator 3 shown in Appendix 1.

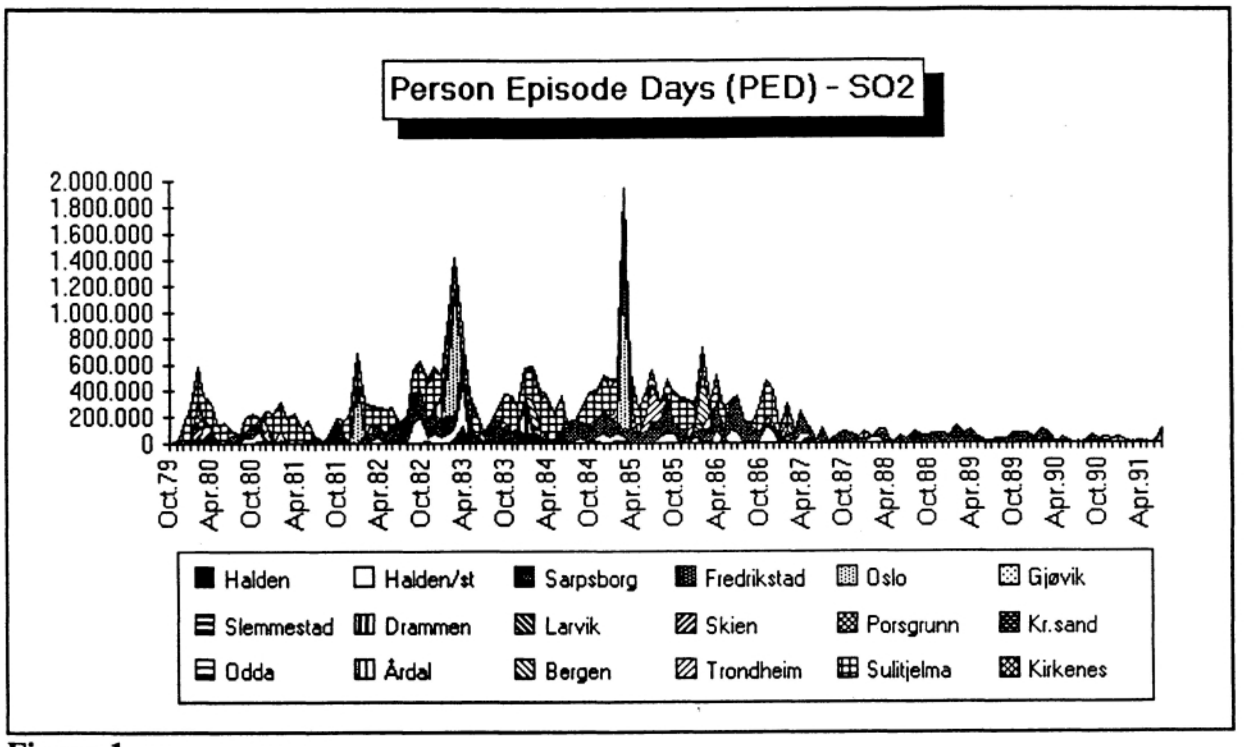

Person Episode Days (PED) - SO2
2.000.000
1.800.000
1.600.000
1.400.000
1.200.000
1.000.000
800.000
600.000
400.000
200.000
0
Oct.79
Apr.80
Oct.80
Apr.81
Oct.81
Apr.82
Oct.82
Apr.83
Oct.83
Apr.84
Oct.84
Apr.85
Oct.85
Apr.86
Oct.86
Apr.87
Oct.87
Apr.88
Oct.88
Apr.89
Oct.89
Apr.90
Oct.90
Apr.91
Halden
Halden/st
Sarpsborg
Fredrikstad
Oslo
Gjøvik
Slemmestad
Drammen
Larvik
Skien
Porsgrunn
Kr.sand
Odda
Årdal
Bergen
Trondheim
Sulitjelma
Kirkenes

Figure 1

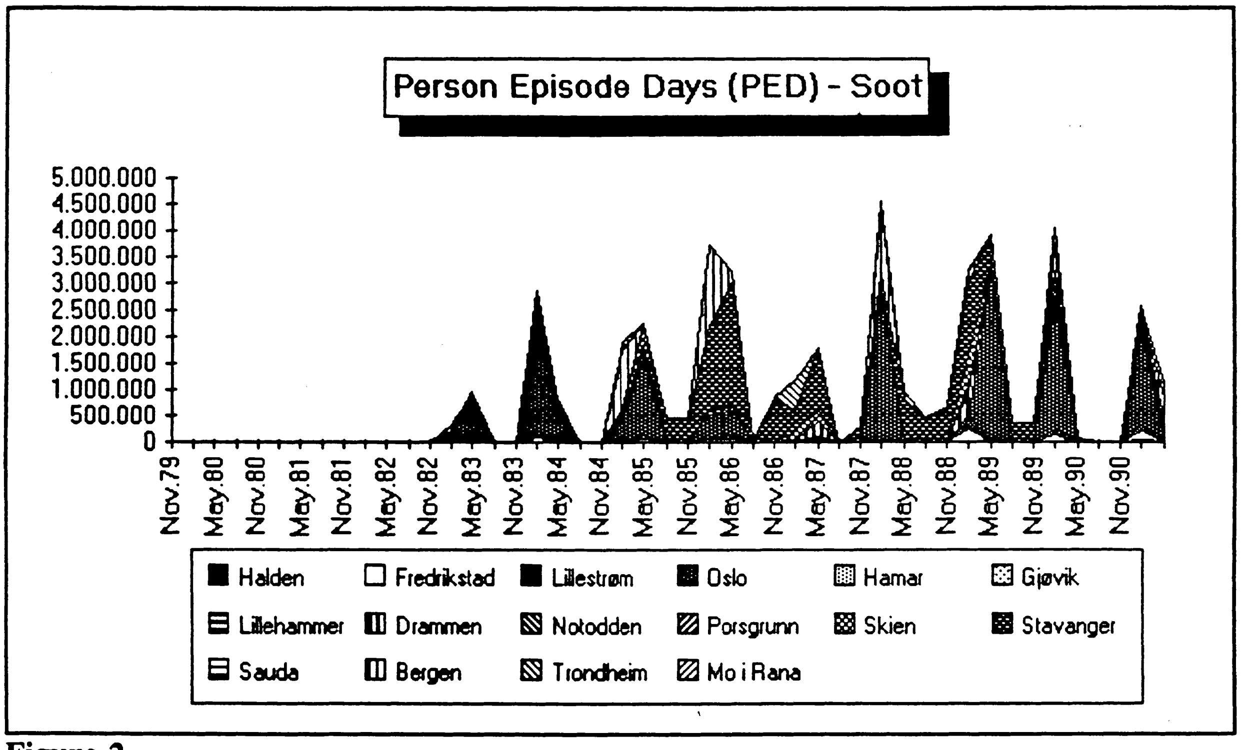


Figure 2

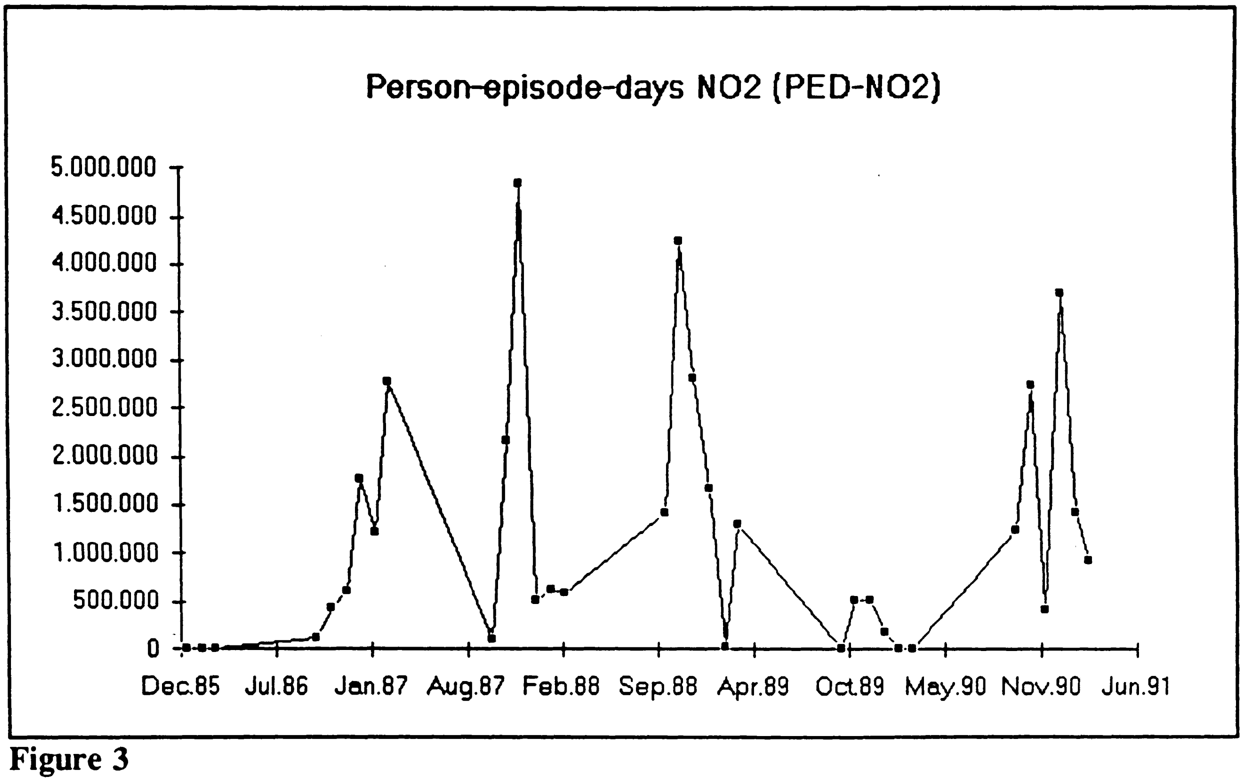


Figure 3

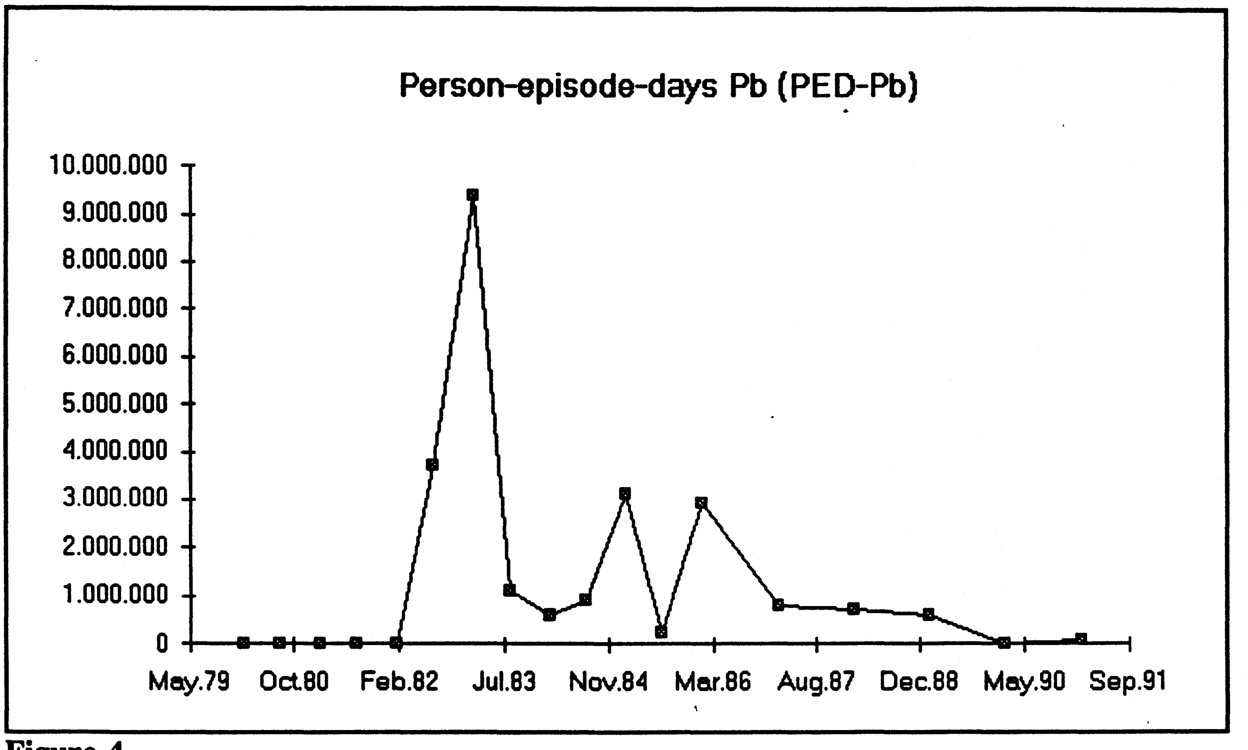
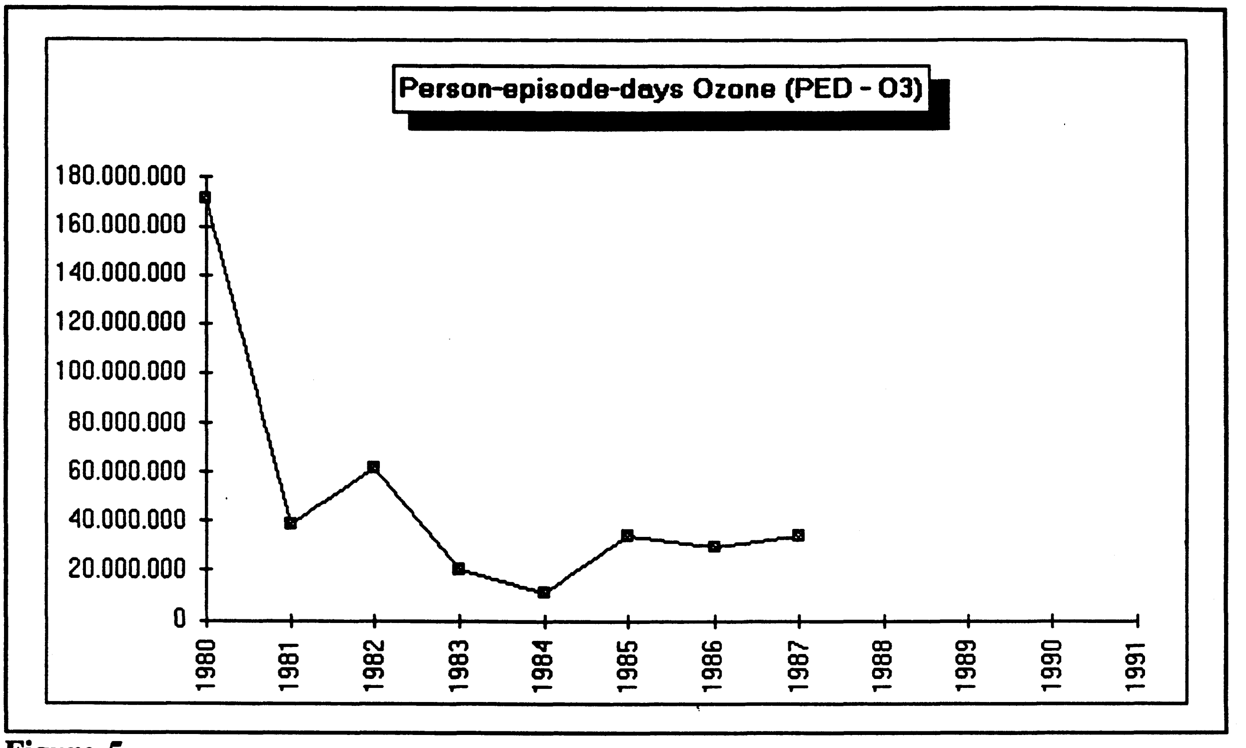

Person-episode-days Pb (PED-Pb)
10.000.000
9.000.000
8.000.000
7.000.000
6.000.000
5.000.000
4.000.000
3.000.000
2.000.000
1.000.000
0
May.79
Oct.80
Feb.82
Jul.83
Nov.84
Mar.86
Aug.87
Dec.88
May.90
Sep.91

Figure 4



Person-episode-days Ozone (PED - O3)
180.000.000
160.000.000
140.000.000
120.000.000
100.000.000
80.000.000
60.000.000
40.000.000
20.000.000
0
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991

Figure 5

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