Environmental Indicators, Their Use and Development in Selected Member States

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The report offers a view of the attitudes of Member States and at international level to the development and use of environmental indicators. The information should be circulated as widely as possible within the Environment Agency to ensure that Regions are aware of attitudes and implementation in other European Countries.

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CONTENTS

		Page
LIST OF TABLES		**ii**
LIST OF FIGURES		**iii**
EXECUTIVE SUMMARY		**1**
KEY WORDS		**2**
1.	**INTRODUCTION**	**3**
2.	**OBJECTIVES AND APPROACH**	**5**
3.	**DEFINITIONS**	**7**
4.	**INDICATOR SYSTEMS**	**9**
4.1	Summary	9
4.2	Introduction	9
4.3	International	12
4.4	National - EU Member States	20
4.5	Discussion	28
5.	**CRITERIA AND APPROACHES FOR SELECTION OF INDICATORS**	**31**
5.1	Summary	31
5.2	Introduction	31
5.3	International	32
5.4	EU Approaches	32
5.5	EU Member States	34
5.6	Discussion	37
6.	**INDICATORS SELECTED AND THEIR USE**	**39**
6.1	Summary	39
6.2	Introduction	39
6.3	OECD and EU approaches	40
6.4	EU Member States	41
6.5	Discussion	51

Page

7. COMPARISON OF INDICATORS **53**

7.1 Summary 53
7.2 Global Warming 53
7.3 Indicators for Eutrophication 60
7.4 Discussion 68

8. CONCLUSIONS **73**

9. RECOMMENDATIONS **75**

10. ACKNOWLEDGEMENTS **77**

REFERENCES **79**

APPENDICES

APPENDIX A INDICATORS SELECTED 83

APPENDIX B EXAMPLE OF SUSTAINABILITY INDICATOR PRESENTATION IN GERMANY 95

LIST OF TABLES

Table 4.1 International indicator systems 13

Table 4.2 National (and Nordic) indicator development 21

Table 5.1 Criteria for indicator selection (OECD 1994) 33

Table 5.2 EUROSTAT criteria for selecting pressure indicators 34

Table 5.3 Scoring table for indicator selection (Walz *et al.*, 1997) 36

Table 5.4 Ideal criteria for indicator selection (HMSO 1996) 37

Table 6.1 Indicator issues covered in reports, or under development, in the three selected countries and the UK, compared with OECD and UN-CSD 42

Table 6.2 Summary of the use of indicators in selected Member States 43

Table 6.3 Precautionary, resource-oriented system of environmental indicators proposed by Loske and Bleischwitz (1996) at the Wuppertal Institute (Germany). 49

Page

Table 7.1 Summary of pressure, state (S) and impact (I), and response indicators proposed or used for global warming internationally and in study countries 55

Table 7.2 Summary of P-S-(I)-R indicators used or proposed for eutrophication internationally and in the study countries 62

Table 7.3 Summary of P-S-(I)-R indicators used for eutrophication of inland waters and marine waters 70

LIST OF FIGURES

Figure 4.1 Illustration of the need for indicators in environmental reporting in Germany (source: Walz *et al.* 1997) 11

Figure 4.2 Pressure-State-Response (P-S-R)model (OECD 1994) 16

Figure 4.3 US-EPA Pressure-State-Response and Effect (P-S-R/E) model 18

Figure 4.4 Driving force-Pressure-Impact-Status-Response (D-P-S-I-R) model of the EEA 19

EXECUTIVE SUMMARY

This report reviews the development, nature and use of environmental indicators in selected EU Member States (Denmark, Germany and Sweden) in order to provide the UK Agencies with intelligence for future policy development in this area. As national indicator systems have been strongly influenced by systems developed at international level, such schemes are also briefly reviewed to set the scene.

Environmental indicator systems have been developed in many international and national arenas to provide a simple picture of the environment. Their most common use is to present environmental information and as performance indicators to measure progress towards specified environmental goals. They have also been adapted for use, together with measures of social and economic development, as indicators of sustainable development, and highly aggregated indices for more simplified presentation of data are also being developed.

The most widely used framework for organising environmental information and developing indicators is the OECD Pressure-State-Response (P-S-R) model. This model was designed as a basis for reviewing environmental performance and has been adapted by other organisations, and refined by some to include driving force (D) and impact (I) indicators, e.g. the D-P-S-I-R model of the European Environment Agency. However, there is considerable variety in indicator systems and in the detailed use of indicators; as a result there is doubt about international and global compatibility of these.

All countries studied recognise the need for environmental indicators; of these, Denmark has the most established system which has been in use since 1991. Sweden and Germany are developing indicator systems, although they have already been in use to some extent for some time, particularly in Germany, for presenting environmental information.

To a large extent, indicators are being selected on the basis of already existing data rather than need; and at times, it seems merely a matter of terminology, to decide whether indicators as such are in fact in use. There should be more emphasis on indicator selection according to need, and focusing on future monitoring requirements.

The most commonly used themes for which environmental indicators have been developed, are: climate, ozone layer, acidification and water resources. Global warming and eutrophication have been addressed in some detail in this report. The most frequently used indicators for global warming are the pressure indicator, CO_2 emission, and the state indicators, CO_2 concentrations and green house gas concentrations. Indicators specifically for eutrophication have not been used or developed in all countries, and there is considerable diversity of approach, probably because of the more localised nature of this area of environmental concern.

In general, state indicators are the most widely used, whilst fewer pressure indicators, and very few response indicators appear to be in use. The latter seem to be more difficult to define, and data is often not readily available. Although indicators have been presented in environmental reports, it is rarely the case that a full picture is provided, i.e. from driving forces to pressures, to states and impacts, and finally responses; even where a full set is presented, the indicators used within a particular issue, are often unrelated. This shortcoming should be addressed when planning the use of indicators and data collection programmes.

As with indicator systems, a wide variety of indicators are emerging; even where they are similar, different ways of expressing them and variable definitions make international comparisons difficult. Efforts are needed to standardise indicators and their presentation.

The search for further simplification of indicator systems, for example for dissemination of easily accessible information to the public, is continuing. With this approach there is a risk of oversimplification which may no longer reflect the true situation. Nevertheless, there is clearly a need for this, and it can be valuable, if the simplified system is based on a thorough scientific evaluation of potential indicators, leading to the formulation of a small number of indices. At the same time, a more complex system of well connected indicators (from each category of the P-S-R or D-P-S-I-R cycle) should be used to examine progress on specific topics in more detail.

KEY WORDS

Environmental indicator, sustainability indicator, indicator development, environmental information, OECD, UN, Europe, Nordic Council, Denmark, Sweden, Germany.

1. INTRODUCTION

Environmental information must serve the needs of a wide variety of users with varying degrees of technical expertise. Whilst, technical specialists in organisations responsible for environmental protection and management require detailed information in order to manage the environment effectively, policy makers and the public, on the other hand, often have the time, interest, or ability to consider only a few pieces of information before they make decisions.

One commonly advocated approach for summarising environmental information for decision-makers is through the use of environmental indicators and environmental policy performance indices. These indicators aim to provide a cheap and reliable means of transforming complicated environmental data into a clear and understandable format. Indicators may be used to monitor the state of the environment, as a basis for making policy decisions, and to assess the impacts of policies and activities on the environment.

Environmental indicators are being developed by national and several international organisations. In the UK, the former Department of the Environment (now the Department of the Environment, Transport and Regions, DETR) has published a report reviewing 21 areas of interest which lists more than 100 indicators as a tool in assessing progress towards sustainability (HMSO 1996). The Environment Agency has also used indicators to report on the state of the environment (EA 1996). In Scotland a working group has been established to identify a single set of indicators that can be used by all involved in environmental protection.

This report reviews the development, nature and use of environmental indicators in other Member States (Denmark, Germany and Sweden) in order to provide the UK Agencies with intelligence for future policy development in this area. As national indicator systems have been strongly influenced by systems developed at international level, such schemes are also briefly reviewed to set the scene.

2. OBJECTIVES AND APPROACH

The overall objective is to review the current use of environmental indicators and indicator reports in selected EU Member States taking into account international requirements for information and to comment on the applicability of some of these indicators to the UK current system.

The detailed objectives are listed below:

- to investigate, critically, the approaches taken by three EU Member States, namely Denmark, Germany and Sweden, to develop environmental indicators;
- to indicate the nature of the environmental indicators that have been developed and used;
- to identify the ways in which environmental indicators are used (for example in national status reports, performance reports, or as a way of targeting actions, evaluating policy impacts and/or investment programmes); and
- to comment briefly on the extent and nature of the data, or of the programmes in place to collect the relevant data, used to support the selected indicators.

In addition, further analysis was sought for two specific sectors of interest, eutrophication and global warming, to illustrate in more detail:

- the nature of the indicators selected;
- the geographical coverage;
- the information used for their formulation; and
- their applicability and suitability for the UK situation.

This report has been prepared from a review of the literature and from personal interviews with a range of key contacts in each of the selected countries as well as from input by Members of the European Topic Centre for Inland Water (ETC/IW). Section 3 reviews and summarises international and national indicator systems in use or under development, Section 4 discusses the criteria and approaches for the selection of indicators, whilst Section 5 covers the indicators selected and used internationally and in the study countries. The environmental issues 'global warming' and 'eutrophication' are addressed in Section 6, with specific reference to the use of indicators. Conclusions are presented in Section 7.

A list of the persons/organisations contacted is given in Section 8. Examples of international and national indicator systems are included in Appendix A, whilst Appendix B shows an example of indicator presentation from Germany.

3. DEFINITIONS

The definitions of the main terms used in this report are largely based on the definitions given in OECD (1994) and are given below:

Environmental Indicator: parameter or value which describes a particular aspect of the state of (pressure on, or response to) the environment with a significance beyond that directly associated with a parameter;

Environmental Indicator System: a set of indicators which describes the state of the environment (quality of environment, quality and quantity of resources), normally including pressures (caused by human activities) on, and responses (societal) to the state of the environment and giving due regard to interconnections between indicators;

Pressure Indicator: Describes pressures on the environment caused by human activities (adverse impact on the environment);

State Indicator: Indicator which describes environmental conditions, in terms of quality or aspects of quantity and quality of natural resources;

Response Indicator: Describes societal responses aimed at improving the state of the environment (beneficial impact on the environment);

Environmental Performance Indicators: Selected or aggregated indicators for the purpose of environmental performance evaluation;

Index: a set of aggregated or weighted parameters or indicators;

Aggregation: combine values or indicators to give an overview (e.g. spatial aggregation: combine local/regional data to represent national situation), or select key factors that give a representative (but simplified) picture of the true situation;

Disaggregation: Provide a more detailed picture, e.g. in spatial terms or in terms of industry-specific sources of pollutants;

Sustainability Indicators: parameters or values which describe aspects of sustainable development with a significance beyond that directly associated with a parameter;

Sustainability Indicator System: a set of indicators which describes sustainability; these will include environmental indicators, as well as socio-economic indicators, and give due regard to interconnections between indicators.

P-S-R: Indicator system using Pressure, State and Response indicators.

D-S-R: Indicator system using Driving force, State and Response indicators.

D-P-S-I-R: Indicator system using Driving force, Pressure, Status, Impact and Response indicators.

4. INDICATOR SYSTEMS

4.1 Summary

There is widespread interest in environmental indicator systems. The development and use of environmental indicator systems is often closely linked to sustainability. At international and national level, the development of both have been strongly influenced by the OECD P-S-R model applied to selected themes.

Some have developed the model further, for example by adding an 'Effects' category, as well as adding natural phenomena to the 'Pressures' (US-EPA). The EEA D-P-S-I-R model subdivides the 'Pressures' category into 'Driving forces' and 'Pressures', and the 'State' category into 'Status' and 'Impact'. The latter model has been represented as a cycle, emphasising the need to consider all categories and thereby closing the loop, i.e. with responses affecting driving forces, or pressures and status directly. This seems to be a particularly important aspect on which any development and application of indicator systems should focus. Another, particularly interesting feature is the system proposed in Germany that indicates links between themes and indicators, where appropriate, for example global warming linked to energy usage.

The national systems examined in this report (Denmark and Sweden including Nordic Countries combined, Germany) are all broadly based on the OECD P-S-R model, although all are still under development to a greater or lesser extent. The most established system seems to be in use in Denmark. In Sweden the approach is rather different from all others; the current emphasis is on the development of 'State ' indicators directly related to the national goals; their intended use is as performance indicators after establishment of environmental quality criteria against which the indicators are to be measured (as ratios). In addition, highly aggregated indices are also being developed, mainly for sustainability, to further simplify data presentation.

The use of a common model at international and national level would be an advantage for the purpose of making comparisons between countries and assessments at international and global level.

4.2 Introduction

This section reviews the different indicator systems developed, or under development, at international and national level. Although the aim of this report is to assess environmental indicators, these are often closely linked with sustainability indicators and it is not always practical to present them separately. Sustainability indicators are therefore also discussed to a limited extent, where appropriate, although focusing on the environmental aspects of sustainable development. The use of environmental performance indicators and (performance) indices is also briefly mentioned.

Because of their influence on approaches at national level, systems developed at international level are reviewed initially, as follows:

- Organisation of Economic Co-operation and Development (OECD);
- United Nations Commission on Sustainable Development (UN-CSD);
- the Scientific Committee on the Problems of the Environment (SCOPE);
- the United States Environment Protection Agency (US-EPA); and
- the European Union (EU): European Environment Agency (EEA) and the Statistical Office of the European Communities (EUROSTAT).

At national level, the following countries are covered:

- Nordic countries (as a group);
- Denmark;
- Sweden; and
- Germany.

4.2.1 Environmental indicators

Environmental indicators have been developed in various international and national arenas and for different information needs. The most important purpose undoubtedly is the simplified presentation of complex environmental data, not only for communicating summarised, easily accessible information to the public, but also to inform policy makers and provide a sound basis for policy decisions. The main aim of environmental indicators has been succinctly represented by Walz *et al.* (1997) in the following diagram (Figure 4.1).

Clearly the simplified representation of the data must be representative of the real situation, i.e. aggregate a multitude of data or parameters, encompassing key factors which can summarise the overall quality of the environment, and focus on the important interactions between different environmental factors, such as driving forces or pressures and responses affecting the quality (impact on the environment and state) of the environment.

Conversely, disaggregation may be used where a more detailed assessment is required, either in spatial terms (i.e. from global to national to local situation) or in terms of specific sources of pollutants (e.g. from overall emission to different sectors of industry). This will be necessary where assessments and actions (responses) need to focus on a local environment or specific industrial sectors.

An alternative to data aggregation, for making large amounts of data more accessible to managers and policy-makers, is data visualisation through graphical approaches, geographic information systems (GIS) and maps. Some authors have advocated multivariate statistical models as alternatives to weighted average indices for determining whether stressed biological communities fall outside normal ranges (e.g., Suter, 1993).

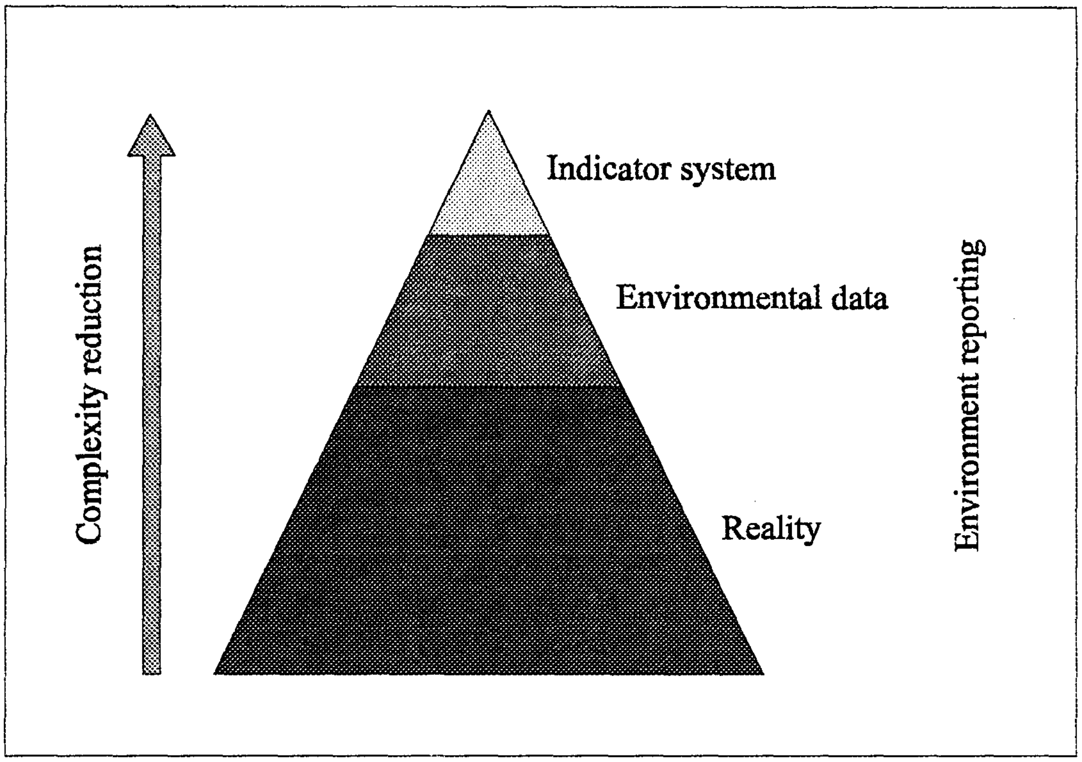

Figure 4.1 Illustration of the need for indicators in environmental reporting in Germany (source: Walz *et al.* 1997)

One simple graphical alternative for reporting on the condition of ecosystems is the 'AMOEBA' approach. It permits visual integration of a number of indicators by presenting the indicator values as segments on a pie diagram, relative to a circle which represents the policy criteria or standards against which observed levels are to be compared. If all indicator values exactly meet the standards, then the diagram looks like a pie with equally shaped wedges. As more and more individual indicators fall short of or exceed the policy criteria (the circle), the diagram begins to look increasingly amorphous, like an amoeba. Multi-dimensional bar charts are an alternative graphical presentation tool with a similar purpose.

4.2.2 Indices

One commonly advocated approach for summarising environmental information for decision-makers is through the use of indices, which are based on a systematic procedure to weight, scale and aggregate multiple variables into a single summary output. Indices can be constructed at various levels of detail and spatial scale, depending on the specific purpose of the index, such as a biotic index for a given ecosystem, an index for global warming potential, or an air pollution index used to report local air quality to the public on a daily basis. Indices can also be constructed for particular environmental issues or themes (see Sections 4.2.3 and 4.2.4 below).

4.2.3 Performance indicators or indices

Environmental indicators can be further developed for use as performance indicators, as developed by the OECD (performance reviews for individual countries, e.g OECD 1994), or as indicators of sustainability as required under Agenda 21, following the 1992 Rio Earth Summit (see Section 4.2.4 below). The development of such indicators may require reference values for 'unaffected' environments to be defined. It also requires the integration of economic, social and environmental issues; this has been started under a EUROSTAT project on environmental pressure indicators or 'green accounting' (EUROSTAT 1997).

Performance can also be assessed through indices for issues or themes, such as the environmental policy performance indices used in the Netherlands to assess progress towards national goals, for example those relating to global climate change, eutrophication, acidification, stratospheric ozone protection and others (Adriaanse, 1993). Each of the Dutch indices combines measures of the emissions of the most important pollutants (pressures) that contribute to a particular environmental problem, and weights these according to their relative contribution. For example, for global climate change, the index is expressed in terms of 'CO_2 equivalents', and is a summation of the Dutch contributions to emissions of greenhouse gases, weighted by the 'global warming potential' (heat absorption capacity) of the individual gases. A line graph is used to depict progress of the index values towards future targets or goals.

4.2.4 Sustainable development indicators and indices

Indicators for sustainable development need to relate socio-economic development to compatibility with a sustainable use of natural resources. A set of sustainability indicators needs to include environmental indicators, as well as socio-economic indicators.

A number of efforts have also been undertaken to develop highly aggregated indices for assessing the environmental, social and economic components of sustainable development at a national level, such as the "index of net resource depletion" generated by the Scientific Committee on Problems of the Environment (SCOPE, 1994) in a draft report for the United Nations Commission on Sustainable Development (UN-CSD).

4.3 International

An overview is provided in Table 4.1 and the various indicator systems are discussed briefly in the following sections.

4.3.1 OECD Environmental Indicators

A widely used framework for organising environmental information and indicators is the OECD 'Pressure-State-Response' (P-S-R) model, as illustrated in Figure 4.2. This approach views human activities as **pressures** which may affect the **state** of the environment; societies then **respond** with environmental, economic and sectoral policies and actions (OECD 1994).

Table 4.1 International indicator systems

Organisation (and Reference)	Purpose	Model	Themes	Indicators
OECD (1994)	Programme of environmental performance reviews of Member States	P-S-R	13 Themes: • 8 Environment; • 4 Resources; • 1 General.	Ranging from 3 to 10 indicators (P, S and R) per theme.
UN-CSD (1996)	To facilitate dissemination and harmonisation of information, and the use of indicators (Agenda 21 - sustainability at national and international level).	D-S-R 'Driving forces' replace 'Pressures' to better describe non-environmental aspects	4 *Categories*, each with several themes: • Social; • Economic; • Environment (12 themes - Agenda 21 chapters); • Institutional.	One or several indicators (D-S-R) developed for each environmental theme: in total 134 indicators; Currently undergoing testing in 11 pilot countries, and to be revised as necessary by 1999.
SCOPE (1994)	Assessment of sustainable development, expressed in *economic terms* Initiative (Agenda 21)	Highly *aggregated* system with few indicators and indices for sustainable development	4 Themes: • Resource use/depletion; • Discharge of pollutants/waste in environment; • Ecosystem status; • Quality of life (impact on human health).	26 indicators (3 of these tentative); Planned to be highly aggregated into 4 indices (one for each theme) with common monetary units.

Organisation (and Reference)	Purpose	Model	Themes	Indicators
US-EPA (1997)	To set and monitor environmental goals	P-S-R/E 'Effects' added to attribute relationships between two or more 'Pressure', 'State' or 'Response' variables; 'Pressures' include natural phenomena.	Themes not specified. 'Pressures' subdivided into underlying (socio-economic), indirect (subcategories: human activities and natural processes), and direct (biophysical stressors). 'State' reflect global, regional, local scale, and includes human health subcategory; 'Responses' subdivided into societal entities (institutions, individuals).	No indicators proposed - these should be set and tailored to specific needs and geographical units.
EEA (1997)	Assessment and reporting on progress towards European environmental targets (5th EAP); Support and feed-back for policy makers.	D-P-S-I-R 'Pressures' subdivided into 'Driving forces' and 'Pressures'; 'State' divided into 'environmental Status' and 'Impact' (c.f. 'Effects' of US-EPA system); 'Response' closes the cycle of interaction.	Environmental issues.	Indicators under development
EUROSTAT (1997)	Communication of information, monitoring impact of environmental policy (5th EAP) and assessment of sustainability.	D-S-R Sustainability indicator system based on UN-CSD.	Environmental issues: 7 problem areas selected from UN-CSD themes (pilot study- sustainability) 10 policy fields (environmental policy - 5th EAP).	Under development: indicators and aggregation into indices; 21 environmental indicators used in pilot study ; 30 indicators for each policy field (5th EAP).

Notes to Table 4.1:

P-S-R: Pressure-State-Response
D-S-R: Driving force-State-Response
D-P-S-I-R: Driving force-Pressure-State-Impact-Response
P-S-R/E: Pressure-State-Response/Effect

OECD: Organisation for Economic Co-operation and Development
UN-CSD: United Nations Committee on Sustainable Development
SCOPE: Scientific Committee on Problems of the Environment,
US-EPA: United States of America Environmental Protection Agency
EEA: European Environment Agency
EAP: Environmental Action Programme

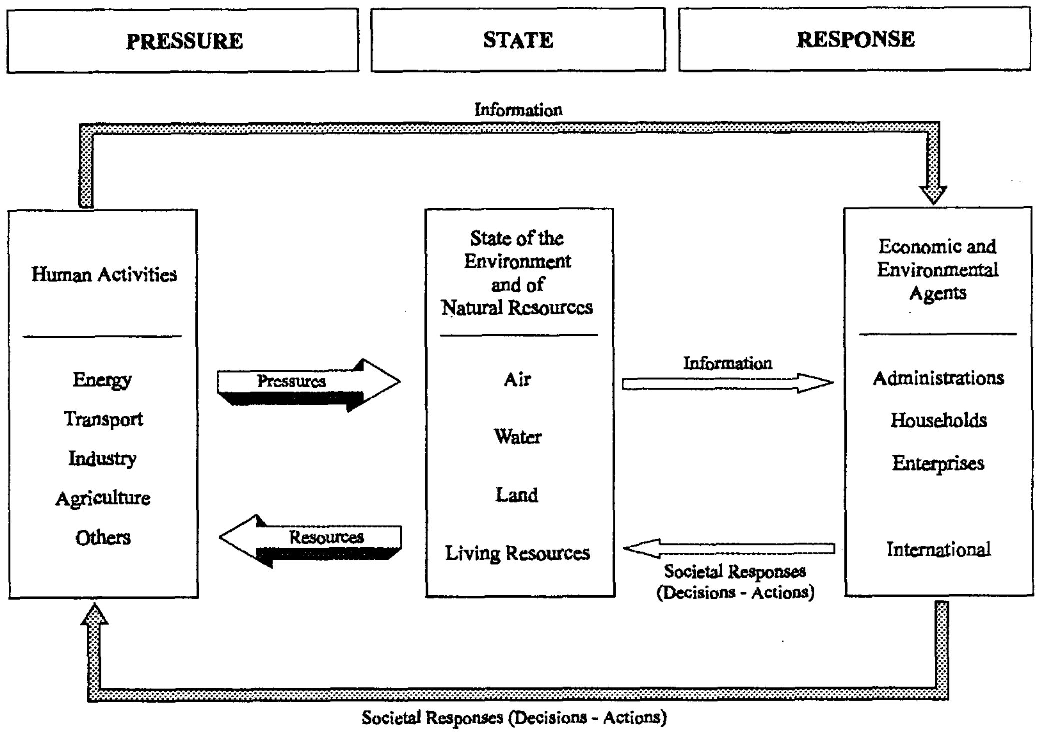

Figure 4.2 Pressure-State-Response (P-S-R)model (OECD 1994)

Under the OECD approach, environmental issues are classified into 13 themes, and P-S-R indicators have been developed for each theme (the themes, together with the indicators, are shown in Table A.1, Appendix A). The majority of themes (8) reflect environmental concerns, while others more strongly reflect resource issues (water, forests, fish, soil), and the last category is intended to provide general information which cannot be assigned to a particular theme. It is planned that pressure indicators, in particular, will be dissagregated to enable the main sectors below the national level to be identified.

The system is being applied in the OECD programme of preparing environmental performance reviews for Member States.

4.3.2 UN-CSD and SCOPE Sustainable Development Indicators

Following the commitment made at the Earth Summit of June 1992 in Rio, the United Nations Commission on Sustainable Development (UN-CSD) adopted a work programme for the development of a set of sustainability indicators. The approach is an adaptation of the P-S-R model with 'pressures' replaced by 'driving forces', i.e. D-S-R, to better describe non-environmental aspects. The structure closely reflects Agenda 21 and is divided into four categories; i.e. social, economic, environmental and institutional, each with several themes (Agenda 21 chapters) (UN-CSD 1996). The 12 environmental themes, and D-S-R indicators developed for these, are shown in Table A.2 (Appendix A). The themes and indicators focus on environmental protection, integrated management, conservation of ecosystems and biodiversity, and sustainable use of resources.

The aim is to provide political decision makers with sustainability indicators, to promote the use of indicators, to facilitate and harmonise dissemination of information on sustainability, and facilitate comparison at national and international level. This approach is therefore well matched to policy development and reporting at an international and national level. Indicators are presented as a matrix against the themes with the intention to balance conformity with flexibility by allowing individual countries to select those indicators most relevant at a national level.

In response to Agenda 21, the 'Scientific Committee on the Problems of the Environment' (SCOPE), which was created in 1969, launched a programme (in 1994) to develop aggregated environmental indicators (indices) for sustainable development. The model uses only four main themes; resource use/depletion, discharges of pollutants/waste into the environment, ecosystem status, and a quality of life function (impact on human health). A total of 26 (three of these tentative) indicators have been developed, focusing on resource depletion, pollutant emissions, geographic distribution of land use and ecosystems, and human exposure to pollutants (SCOPE 1994, see Table A.3, Appendix A).

The model allows for integration of economic, environmental and social aspects of sustainable development. For each theme it proposes highly aggregated indices which attempt to assesses non-sustainable resource use in economic terms, such as 'index of net resource depletion' which tries to quantify long-term, irreversible losses of ecosystem components or functions in monetary terms. In practice, however, the planned aggregation to four indices may only be realisable in the long-term.

4.3.3 US-EPA

The US-EPA has proposed a framework which builds on the OECD P-S-R model. It is called the P-S-R/E framework and stands for Pressure-State-Response and Effect model (see Figure 4.3).

The proposed EPA model is broader than the OECD model with the different P-S-R categories being more detailed. An additional 'Effects' category has been added which appears to largely correspond to the Impact category of the EEA/D-P-S-I-R approach (see Section 4.3.4 below).

Perhaps the most interesting aspect of this model is the attempt to include separately identifiable values for natural processes which contribute to changes in the quality of the environment. However, within this elaborate conceptual framework, indicators have not been specified and the US-EPA maintains that these should be tailored to specific user needs and geographic units. This approach could lead to considerable diversity of indicators, and possibly defy the overall purpose of simplification and comparability on a national and international scale.

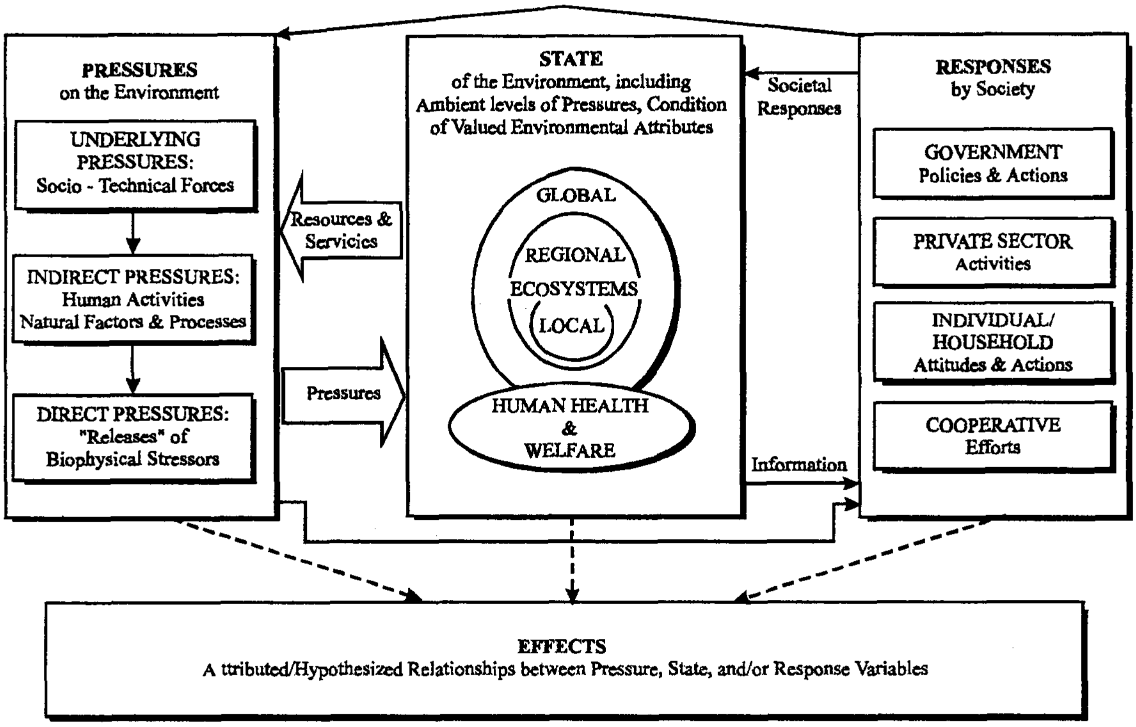

Figure 4.3 US-EPA Pressure-State-Response and Effect (P-S-R/E) model

4.3.4 European Union (EU)

EEA Driving force-Pressure-Status-Impact-Response (D-P-S-I-R) model

Although the OECD/P-S-R model is widely used by individual Member States, it has been criticised as being too fragmented, static and too focused on resources and economics (EEA and SwEPA 1997). The EEA has adapted the P-S-R model, expanding it to create the D-P-S-I-R model, i.e. 'Driving forces', 'Pressures', 'Status', 'Impact' and 'Responses' (Figure 4.4). In this model, 'Pressures' are sub-divided into 'Driving forces' and 'Pressures', 'State' is sub-divided into 'Environmental Status' and 'Impact', and the entire model is shown as a cycle, illustrating the importance of the links between the different categories and the need for consideration of all the categories to close the loop. A similar, recently published model also shows that responses may affect pressures or status directly (EEA 1998).

Chemical and physical parameters fit into the P-S-R model, as there is a clear causality chain and they provide an indication of environmental state, although they may suffer from time-lags (i.e. only after a certain period can successes or failures of policies be noted). (EEA 1995a). Biological parameters fit less easily into the 'state' indicator section, as there is a less clearly defined causal relationship between pressure and state (e.g. unknown factors or combinations of pressures, as well as time delays). However they provide a better indication of ecological impact as they integrate the effects of multiple pressures which might be missed by the use of physical or chemical parameters alone. Their inclusion into this D-P-S-I-R model therefore enables the refinement of state indicators to ensure they are ecologically relevant.

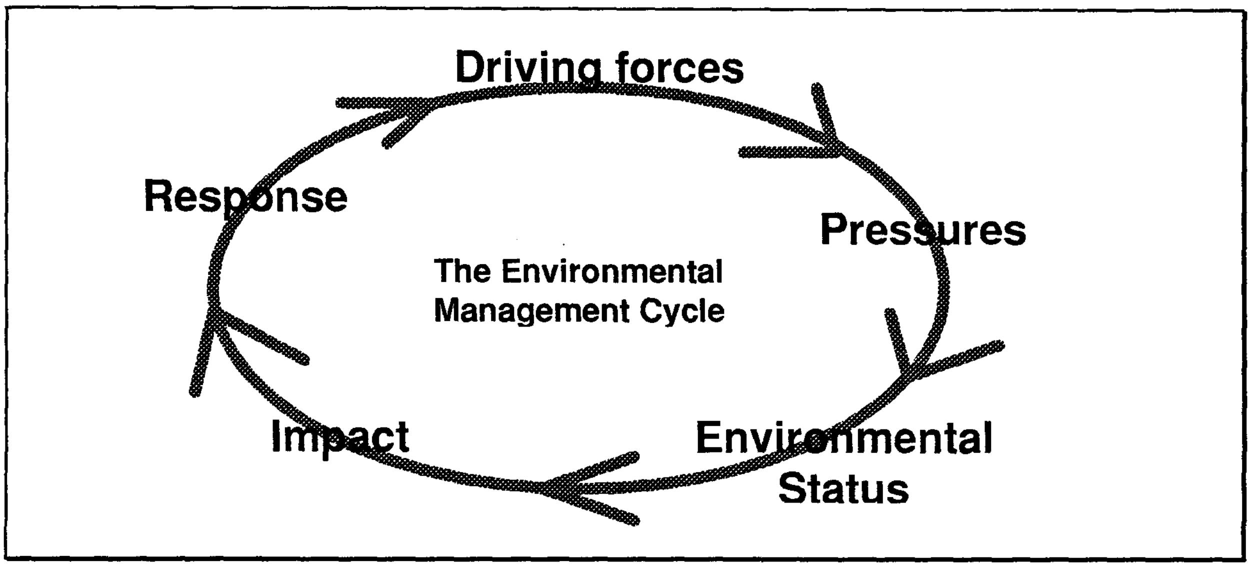

Figure 4.4 Driving force-Pressure-Impact-Status-Response (D-P-S-I-R) model of the EEA

The model has been developed to assist in one of the EEA's tasks, namely to produce a state of the environment report assessing measures taken towards achieving the targets set in the 5th Environmental Action Programme (5th EAP). The EEA is currently developing a new annual reporting format instead of the three year-Dobriš report (EEA 1995, EEA 1998), although it will be similar to that previously used. A slightly modified D-P-S-I-R framework is expected to be used as the basis for structuring the environmental issues and for selecting a limited number of indicators for more frequent publication.

In addition to providing information to the public, the presentation of trends in environmental indicators will be crucial for supporting the policy process and providing sufficient feed-back for policy makers on the impacts of their present policies, as well as providing a basis on which to predict the impact of future policies.

EUROSTAT model for sustainable development indicators

The EUROSTAT model for sustainable indicators is based on ideas developed by the UN-CSD. The model adopts three types of indicators as in the UN-CSD approach; driving force indicators (human activities having an impact on the environment), state indicators (snapshot of existing situation, but including trends where feasible) and response indicators (outline measures).

The project will comprise economic, social, environmental, and institutional indicators, and cover the EU Member States. A pilot study has been undertaken and the results published (EUROSTAT 1997). Groups of experts were asked to select the most relevant themes and indicators. In the environmental field, seven of the UN-CSD themes with 21 indicators have been selected for the pilot study. These are predominantly pressure indicators, although a few state indicators and response indicators are included.

A pilot study is currently also being undertaken on sector-by-sector indicators, including aggregation of economic, social and environmental measures; this will be followed by a more detailed statistical analysis (S. Nixon, ETC/IW, personal communication).

EUROSTAT, through wide ranging consultation of experts in EU Member States, is also developing a set of environmental pressure indicators for monitoring the impact of environmental policy under the 5th EAP. This involves the selection of indicators for ten problem areas (see Section 5.2).

The main purpose of the projects is to assist the communication of information on EU Member States, and to have a basis for assessing sustainability and the impact of environmental policy.

4.4 National - EU Member States

Table 4.2 summarises indicator systems in the countries studied and these are discussed briefly below. The Nordic Countries as a group (members: Denmark, Finland, Norway, Sweden) have been included in this section because of the overlap with the countries studied, i.e. Denmark and Sweden as members of the Nordic group.

4.4.1 Nordic Countries

The Nordic set of environmental indicators (Nordic Council of Ministers 1997) was developed by the Nordic Indicator Group (NIG), is based on the P-S-R concept and has its foundation in the OECD Core Set (OECD 1994). The 13 themes have been adopted with slight modification: thus, the OECD theme 'Biodiversity/landscape' has been split into two themes, 'Biodiversity' and 'Cultural landscapes', and the 'General' theme has been used for 'Agricultural land resources'. The OECD indicators have also broadly been adopted with some modifications to suit the Nordic conditions

Due to the considerable differences between definitions, classification and methods of measurement across the Nordic Council Member States, the NIG is concerned about the validity of comparing the different sets of data, and is currently engaged in standardising the data requirements for the different indicators.

4.4.2 Denmark

The P-S-R model has been used in Denmark to develop environmental indicators. However, NERI recommend that the model should be refined by stating the links between driving force, pressure, state, impact and response for each indicator (i.e. similar to D-P-S-I-R). NERI is playing an active role in benchmarking indicators and seeking to improve the link between indicators and the real situation through testing and adjusting the selection of indicators as necessary (P. Kristensen, personal communication).

Table 4.2 National (and Nordic) indicator development

Country	Purpose	Model	Themes	Indicators
Nordic Countries	Environmental Assessment, including monitoring of achieving goals, (international agreements).	P-S-R	OECD core set of 13 themes with slight modification.	OECD core set of indicators with some modifications; Committee currently attempting to standardise indicator data across Nordic Member States.
Denmark	Environmental reporting; Assessment in relation to environmental goals; and Basis for policy development.	P-S-R (D-P-S-I-R)	Environmental issues (7 in Environmental Indicator Report 1996) but may be expanded through continuous assessment and further development.	55 indicators used in environmental status reports; Further development to establish D-P-S-I-R links for each indicator; Benchmarking exercise and research for continuous assessment and adjustment of the system.
Sweden	Measure progress towards 18 national goals (performance indicators); Measure Government progress towards ecologically sustainable society (for reporting to Parliament).	P-S-R but focus on 'State'; SDR (sustainable development records); 'Green ratios' (ecological sustainability).	3 categories focusing on environment, resources and pollutants: • land and water use; • resources and management; • pollutants. Themes equal to 18 (proposed) national objectives.	Environmental indicators under development, emphasis on state indicators and development of baseline standards (environmental quality criteria) (state indicator versus baseline ratio as performance indicator); Outline set of sustainability indicators (now termed 'Green ratios', 3 themes, 16 'ratios') recently presented to Government (ecological sustainability).

Country	Purpose	Model	Themes	Indicators
Germany	Environmental reporting; Assessment of progress towards sustainability.	P-S-R (driving force also used to some extent, e.g. with respect to sustainability, includes testing of UN-CSD system). Sustainability: Recent proposal to develop a set of 6 'Environmental Barometers' reflecting 6 key environmental themes.	Main proposed system for Federal use is based on the OECD set, with some modifications, i.e. additional theme: radiation (total 14 themes); Various other systems have been proposed and are still under development, but broadly based on OECD model (mainly concerning sustainability).	Indicators under development 100 short/medium term, 40 long term proposed, but already in use to some extent (environmental reporting at Federal level and in one Federal State).
UK	Reporting on the state of the environment; and Monitoring progress towards sustainability.	P-S-R (plus impact to some extent).	Pressure and response indicators both include adverse and positive impact indicators; Sustainability indicators include state indicators to measure state of economy.	Indicator system used in report on the environment in 1996.

Since 1991, reports on the state of the environment in Denmark have been structured according to the P-S-R framework, presenting information through 55 indicators for seven main environmental issues (MEM 1996). These and other reports on the environment satisfy the need to collate and disseminate information, help to assess whether environmental objectives are being met, and appear to be used also as a basis for policy decisions and strategic planning.

4.4.3 Sweden

Environmental indicators

Sweden has been involved in a number of studies to develop and present environmental indicators on a Europe-wide (EEA and SwEPA 1997) and Nordic Country-wide (Nordic Council of Ministers 1997) scale. However, on a national scale, environmental indicators have not been produced but research into this area is currently being carried out.

Sweden produces annual reports, 'Progress so far', which aim to assess its progress in meeting the National Environmental Objectives. Analyses carried out in these reports have resulted in the recognition that the objectives and the instruments used to measure them needed to be revised; for example, some objectives were very precise, e.g. CO_2 reduction targets, and, as such, it was very easy to check whether progress had been made in meeting them. Other objectives, however, for example biodiversity, were not clearly formulated and, therefore, had to be evaluated using the sum of the various components that make up biodiversity.

Consequently, the Swedish Environmental Protection Agency (SwEPA) proposed a reduction of its 167 national environmental objectives to 18 national objectives (SwEPA 1997) aimed at achieving the four national goals set by the Riksdag (Ministry of the Environment 1996):

- protection of human health;
- preservation of biodiversity;
- creation of good long-term management of natural resources; and
- protection of the natural and man-made landscapes.

The 18 new national objectives focus on nature conservation, resources and pollutants, grouped into three categories (Land Use and Water Use; Resource and Management; and Pollutants).

Once adopted, these would be used to 'systematise, co-ordinate and update earlier objectives in order to clarify the situation and put the objectives in an overall context' (Notter and Helsten 1997). The new objectives would describe and define the state of the environment necessary to achieve a sustainable society.

To measure the progress towards these objectives, it is intended that P-S-R indicators (with some additional driving force indicators for sustainability) will be used with the national objectives broadly forming the themes on which to select the indicators. However, current work appears to focus on state indicators only. Most of the response indicators are likely to be derived from the original 167 environmental goals, whilst pressure indicators are not being addressed at present.

Within the current programme of indicator development, there is considerable emphasis on developing baseline criteria, against which state indicators may be compared, and also for the purpose of setting targets. To this end, the Swedish Environmental Protection Agency (SwEPA) is developing the Environmental Quality Criteria (EQC) methodology based on ecological criteria using chemical, physical and biological parameters. The methodology is derived from that currently used in Norway and the SwEPA's previous experience in deriving its Quality Criteria for Lakes and Watercourses. Basically, it involves the use of an 'anthropogenic influence ratio (AIR) obtained from comparison of the current state value (SV) with the reference value (RV - baseline value reflecting pristine state). A ratio of SV/RV equal to 1 indicates no effect, whereas SV/RV = >1 signifies an increase in contamination or exploitation of a resource and may require a response; the latter is assessed on the basis of AIRs for several parameters and other data/scientific knowledge.

The immediate aim is to apply the EQC methodology to six different types of environmental themes.

Policy decisions are also made at the municipal level, where it is envisaged that the greatest demand for EQCs and indicators will be.

Sustainability indicators

The development of environmental indicators is closely linked with the development of sustainability indicators. The Swedish Environmental Advisory Council (SEAC) was commissioned earlier in 1997 to develop a set of national ecological sustainability indicators. The main objective was to indicate the progress made towards achieving an ecologically sustainable society in simple terms. The brief for the Council was to produce a few selected indicators, i.e. with a high degree of aggregation. The indicator themes indicators should relate to the National Environmental Goals and the 18 objectives (if adopted). The Council intends to use three types of indicator: pressure (including some driving force indicators), state and response. In addition, the indicators are to be based on existing, international indicators and developed using the SDR (Sustainable Development Records) methodology.

SEAC is being advised by the Stockholm House of Sustainable Economy (NKH) which has developed SDR for businesses to report on their environmental performance. This is a more managerial approach originally developed for the private sector which is environmentally aware, and is based on a holistic approach, incorporating social, economic and environmental factors into a management system. The system is currently being used by some companies and municipalities, but is also being adapted to report on progress of Baltic 21, a joint sustainability initiative by the countries bordering the Baltic. Its relevance to the national approach is also being examined.

The sustainability indicator system was due for completion in 1998 and expected to be used, in part, to monitor progress towards meeting the national environmental goals, providing early warning if developments were not going in the desired direction, i.e. ecologically sustainable development. Presentation to the Government of an outline set of ecological sustainability indicators has recently been announced (ENDS 1998). However, in its deliberations, the SEAC has abandoned the term 'indicators' and used 'green ratios' instead, although in practice, only a few of the proposed 'green ratios' are in fact ratios (e.g. emissions of carbon dioxide in relation to added value in various sectors). A total of 16 'green ratios' have been selected for three themes ('efficiency objective', 'environmental objective', and 'conversion of households, enterprises etc. to ecologically sustainable development') (SEAC 1998). The 'green ratios' are a mixture of largely unrelated pressure, state and response indicators. The SEAC also recommended further development of other ratios and identified a few key ratios for which inadequate data were available.

4.4.4 Germany

In order to improve the description of the environment and the evaluation of its status, as well as to support the development of environmental indicator systems at international level, particularly the OECD, the Federal Environment Agency *(Umweltbundesamt - UBA)* funded a research project between 1994 and 1996 at the Fraunhofer Institute in Karlsruhe, to further develop indicator systems for environmental reporting. Although the emphasis of the project was on environmental indicators, some aspects of sustainable development indicators were addressed briefly during the final stage of the project.

In addition, there are many other projects in Germany aimed at the development of indicator systems, including some at regional (individual State) level and local (Town and District) level, and these include a variety of approaches. On the whole, most of these seem to be aimed predominantly at indicators for sustainable development, though in this report we will focus on environmental indicators as far as possible.

It must be noted that, although indicators are already being used to some extent in environmental reporting, the development and testing of indicator systems in Germany is still on-going and most of the information obtained for the purpose of this report relates to research projects on the subject. It has also been stressed that there should be no rigidly fixed system, allowing scope for continuous testing and revision, as appropriate. The indicator system proposed by the UN Commission on Sustainable Development (UN-CSD) is currently being tested in Germany and other pilot countries.

In the context of sustainable development, the German Environment Ministry has recently presented a framework for a 'Programme on key environmental areas' which is to include annual reporting of six 'environment barometers' intended to cover the areas: climate, air, land, nature, water, and resources (ENDS 1998a).

The main projects for which information has been obtained are briefly outlined below.

a) Environmental indicators for use at Federal level (research at Fraunhofer Institute - Systems and Innovation Research, Karlsruhe)

The project carried out at the Fraunhofer Institute, Karlsruhe (Walz *et al.* 1995, 1996, 1997) is probably the most important with respect to environmental indicators at national level. It was funded by the UBA to support the introduction of an Environmental Indicator System of reporting at Federal level, by further developing and adapting existing indicator systems.

The overall objectives of the project were listed as follows:

- to improve the information on the state of the environment;
- to improve the exchange of information (communication) on the state of the environment (see also Figure 4.1; and
- to serve as an aid for environmental policy.

Following a review of other national and international indicator systems, the development of the German indicator system was based on the OECD approach. It was considered that the P-S-R approach proposed by the OECD was being widely accepted and would be compatible internationally. In addition, it seemed to be the most suitable approach for achieving a workable compromise between the different requirements.

However, the OECD system was slightly modified to suit its application in Germany. The classification into environmental themes was broadly adopted, with some differences of emphasis, as for example, more focus on quality, less on resources, and the addition of the environmental theme 'radiation'. Thus, the German approach places more emphasis on the ecological impact of indicators, compared with the OECD approach. For example, the OECD themes of water (Water Resources) and forest (Forest Resources) are focused on these environments as resources, whereas the German themes have shifted the emphasis towards the ecological aspects, i.e. 'Water Resources and Water Quality', and 'Forests' (see also Section 4, Criteria for selection of indicators, and Table A.4, Appendix A which lists the proposed indicator system).

Although very similar to the OECD approach, a particularly interesting feature of the above system is the inclusion, where appropriate, of links to other themes and indicators.

b) Environmental indicators used at Federal State level (Landesanstalt für Umweltschutz - LfU - State Institute for Environmental Protection, Baden-Württemberg, Karlsruhe)

The main purpose of this project was the use of indicators in the environmental status report at individual State (Baden-Württemberg) level with the emphasis on environmental indicators (ecological effects).

The 14 themes and PSR environmental indicators proposed in the Fraunhofer study, were assessed for their use in presenting the state of the environment of the Federal State of Baden-Württemberg; of these, 16 indicators were selected as the most representative of the relevant problem areas, and with data available for immediate application (Oelsner 1997). This included key pressure indicators, mainly resource oriented, relevant to Baden-Württemberg, a set of state indicators considered to be the most important in reflecting environmental problem areas, as well as a few response indicators which would provide an overall indication of developments and effects of policies on the environmental status.

By having selected indicators which are likely to be used (or already in use) at Federal level, the system of communication from individual State to Federal level was ensured.

c) Sustainable development indicators for use at Federal level (Wuppertal Institut für Klima, Umwelt, Energie - Institute for Climate, Environment and Energy)

The main focus of this work is on sustainable development. The approach is also based on the P-S-R model and focuses on a precautionary approach to conservation of natural resources. The proposed indicators for resource pressures are summarised through highly aggregated usage values for materials, energy, water and land area. The proposed system of environmental indicators is characterised by a highly aggregated system of impact-related indicators relevant to health and environment, including considerations of risks to human health, damage and reduction in 'buffering capacity' of ecosystems, reductions in biodiversity, and resource depletion. The main proposed responses focus on reductions in contaminant input and resource depletion (Loske and Bleischwitz 1996).

d) Sustainable development indicators at Federal State level (Akademie für Technikfolgenabschätzung in Baden-Württemberg - AT-BW - Academy for the Assessment of the Effects of Technology, Stuttgart)

This project which was supported by the State authorities of Baden-Württemberg, focused on the development of indicators for sustainable development of the State of Baden-Württemberg. The proposed indicator system includes socio-economic factors, is strongly resource oriented, assigns values to 'man-made capital' (based on theory of economic welfare), and proposes a compromise between 'weak' (balance between natural resources and man-made capital) and 'strong' (no depletion of natural resources) sustainability (Pfister and Renn 1996 and 1997, Pfister *et al.* 1997).

The basis for setting environmental indicators is similar to that proposed in the Fraunhofer study (P-S-R) and the selection of themes (sustainability categories) is also similar, although urban environmental quality, fish resources, radiation and general indicators were omitted, because these were not considered important in the context of sustainable development in the state of Baden-Württemberg.

However, the most important, additional theme is 'man-made capital'; this is used throughout to propose compensation for depletion of natural resources or increases in pressures. Man-made resources include not only material resources, but also immaterial resources, such as knowledge. In order to account for the demographic development, a per capita value is assigned. Another important category is 'the import of non-renewable resources'; this is included to ensure that sustainability is not achieved at the expense of other countries or regions.

e) Sustainable development indicators at local/regional level (Forschungsstätte der Evangelischen Studiengemeinschaft - FEST - Research Institute of the Protestant Churches, Heidelberg)

This study focuses on sustainability at local and district level. It was developed for, and tested in the town of Heidelberg and the district Rhine-Neckar in Baden-Württemberg; there is a strong emphasis on environment/ecology and sociological considerations, and it includes economic factors (Diefenbacher *et al.* 1997). However, the researchers proposing this system, are opposed to the inclusion of a value for man-made capital, which forms the basis of the system developed at AT-BW (H. Diefenbacher and G. Pfister, personal communications).

4.4.5 United Kingdom

In the UK, the former Department of the Environment (now the Department of the Environment, Transport and the Regions, DETR) has reported progress towards sustainability based on a preliminary set of indicators (HMSO 1996). The Environment Agency has also used indicators to report on the state of the environment (Environment Agency 1996).

In both cases, the P-S-R model has been used as a basis for developing environmental indicators. Responses which constrain the activity of the economy in order to protect the environment are also regarded as pressures because they may reduce the ability to create wealth and welfare, and in turn inhibit the development of solutions to environmental problems. State indicators have therefore been selected to reflect the state of the economy as well as the state of the environment. They attempt to measure the state of the economy and the quality of the environment, as well as the stock and quality of natural resources. Pressure and response indicators both illustrate impacts on the environment and the economy, caused by human activities. In the environmental indicator model, pressures are seen as adverse impacts while responses are beneficial impacts.

The Scottish Environment Protection Agency (SEPA) has not explicitly used an indicator system in its '96 State of the Environment Report' (SEPA 1996), although many of the illustrations could be regarded as indicators, mainly of pressures and state of the environment, focusing on three themes (air, land and water). SEPA has established a working group to identify a single set of indicators that can be used by all involved in environmental protection.

4.5 Discussion

Environmental indicators are being developed and used at international level and in the countries studied. Due to the current general interest in sustainable development, indicator systems often focus on this aspect and there is considerable overlap between purely environmental, and sustainability indicator systems. The latter focus on resources and comprise environmental, as well as socio-economic, and sometimes institutional indicators.

At international and national level, the development of environmental and sustainability indicator systems has been strongly influenced by the OECD 'Pressure-State-Response' (P-S-R) model applied to selected themes, although some refinement of the approach has also been attempted. Some have developed the model further, for example by adding an 'Effects' category, aimed at describing relationships between indicators, as well as adding natural phenomena to the 'Pressures' (US-EPA). The EEA has added two additional categories, 'Driving force' (human activities affecting the environment) and 'Impact' to better describe ecological or other effects on a given state of the environment.

It is important that refinements should focus on the connections between the different categories, and choose indicators which relate to these connections. This need has been best illustrated in the EEA D-P-S-I-R model, represented as a closed cycle, i.e. with responses affecting the driving forces. In addition, the main system proposed in Germany indicates links between themes and indicators, where appropriate, for example global warming linked to energy usage.

Although all national systems examined, are broadly based on the OECD P-S-R model, the approach in Sweden seems rather different from all others; there the current emphasis is on the development of 'State' indicators directly related to the national goals; their intended use is as Performance Indicators after establishment of environmental quality criteria against which the indicators are to be measured (as ratios).

A further simplification of data can be achieved through the formulation of Indices (aggregated or weighted parameters or indicators); these are being developed, particularly as sustainability indicators.

The use of a common model at international and national level, whether in a purely environmental context or in terms of sustainability, should be encouraged and maintained in order to facilitate future comparisons between countries and meaningful assessments at international and global level.

5. CRITERIA AND APPROACHES FOR SELECTION OF INDICATORS

5.1 Summary

As with the development of indicator systems on the whole, criteria for the selection of indicators, internationally and national are generally closely based on the criteria used by the OECD, i.e. policy relevance, analytical soundness and measurability; this should contribute to international compatibility of indicators.

An important, additional concept for pressure indicators has been introduced by EUROSTAT, namely 'response elasticity', relating to the ease with which responses (actions) can be implemented in practice. German researchers have stressed the importance of ecological soundness of indicators and have prepared detailed background information for each theme before selecting indicators, whilst work in Sweden focuses on linking indicators to national goals and establishment of environmental quality (baseline) criteria.

As far as it has been possible to establish, the main contributors to indicator selection are the scientific community, though economists are also involved, and a variety of interest groups are being consulted in some instances, mainly in relation to sustainability indicators.

Overall in practice, the main driving force in indicator selection appears to have been data availability rather than need.

5.2 Introduction

The aim of developing indicators is to present environmental data in an easily assimilable way, to help formulate policy, set targets and monitor progress towards achieving these targets.

The selection and degree of aggregation of indicators is a critical issue as the indicator system has to be simple enough to aid clarity of communication and be practical to implement, but sufficiently complex to address specific issues in a meaningful way.

The degree of aggregation of indicators is relevant for both communication purposes (e.g. national reports) and policy implementation (e.g. disaggregation to a sectoral level suggests they may be able to be used to influence policy decisions at this level). The simplicity/complexity of the 'ideal' indicator will vary according to audience and its purpose; audiences (public, politicians, scientists) should thus be taken into account when selecting indicators.

If an indicator is to be effective it should be sensitive to change, supported by reliable, readily available data and understood and accepted by intended users. Cost and practicality are therefore important considerations. Initially, less than 'ideal' indicators, for which data are available, may have to be used until a more refined set of indicators is developed in the longer term.

This section explores the criteria used for the selection of environmental indicators at international (OECD and EU) and national level (Denmark, Sweden, Germany).

5.3 International

OECD (1994) has defined three basic criteria for indicator selection; policy relevance, analytical soundness and measurability.

Table 5.1 provides a breakdown of these general criteria which formed the basis for selection of the OECD set of indicators. They represent a useful general summary of criteria which others have also used, some with a slightly different emphasis. Adriaanse (1993) emphasised simplification, quantification and communication, by stating that these were the three essential qualities of indicators whilst Anderson (1991) emphasised the need for indicators to have resonance with the audience to which they are addressed.

5.4 EU Approaches

For the Dobriš report (EEA 1995), environmental indicators were selected on the basis of existing international indicator sets, such as OECD, with the main criteria being the ability to provide an indication of key pressures/stresses on environmental quality in relation to the key 5th EAP themes, and data availability (EUROSTAT and other official sources) for the European countries covered by the report.

EUROSTAT, when developing a set of environmental pressure indicators for monitoring the impact of environmental policy under the 5th EAP, approached European environmental experts (around 2300 experts were contacted and more than 600 replied) to propose a list of indicators. A total of more than 2700 indicators were suggested. The set had to be reduced to a more manageable size and the list was restricted to a maximum of 30 candidate indicators for each of the 10 policy fields covered by the project. Experts were then asked to rank the indicators according to a number of criteria listed in Table 5.2 (excluding the financial cost of data collection). These criteria are based mainly on the OECD criteria (see Table 5.1). This broad consultation was an important step in ensuring proper representation of all national experts and identification of important indicators not yet covered by other international programmes and to ensure that such gaps are given appropriate attention in the data collection planning of Member State statistics services. The final selection amounted to 60 indicators.

Table 5.1 Criteria for indicator selection (OECD 1994)

Policy relevance and utility for users • provide a representative picture of environmental conditions, pressures on the environment or society responses; • be simple, easy to interpret and able to show trends over time; • be responsive to changes in the environment and related human activities; • provide a basis for international comparisons; • be either national in scope or applicable to regional environmental issues of national significance; • have a threshold or reference value against which to compare it so that users are able to assess the significance of the values associated with it.
Analytical soundness • be theoretically well founded in technical and scientific terms; • be based on international standards and international consensus about its validity; • lend itself to being linked to economic models, forecasting and information systems.
Measurability The data required to support the indicator should be: • readily available or made available at a reasonable cost/benefit ratio; • adequately documented and of known quality; • updated at regular intervals in accordance with reliable procedures.

For the water pollution/water resources policy field, the first questionnaire was sent to around 300 national experts. The analysis of the responses showed a great variety and heterogeneity. To aid the selection process, two main categories were specified; quantitative and qualitative; the indicators were further classified according to the type of water (surface/ground); type of pressure (point source, diffuse, accidental), parameters (quality), source of pressure (sectors). seven quantitative and 13 qualitative issues were identified (combinations of type of water, pressure, parameters and source). On this basis, a list of 30 indicators was established (S. Nixon, ETC/IW, personal communication).

The above selection process introduced an important criteria not expressed in other compilations of criteria, namely the 'response elasticity' (see Table 5.2) relating to the ease with which responses (actions) can be implemented in practice and, consequently, whether there is a realistic potential for improvements.

Ideal state indicator characteristics have been compiled for the EEA by the Swedish EPA (EEA and SwEPA 1997). These are again based on generally accepted principles but additional, specific emphasis was placed on the following:

- Biological relevance of indicators (biological parameters, or chemical/physical parameters closely linked to biological effects);

- Early warning function;

- Insensitivity to spatial level (i.e. wide geographical applicability).

Table 5.2 EUROSTAT criteria for selecting pressure indicators

Policy relevant (ranking 1-4)	How important would the pressure indicator be to a national policy maker, e.g. in the environment ministry of your country?
Analytical soundness (ranking 1-4)	How strongly do you consider changes in each indicator would correlate with real changes of the environmental pressure affecting this policy field?
Response elasticity (ranking 1-4)	Given the present technical and economic obstacles, how difficult would it be to take action to significantly reduce each pressure indicator (e.g. by 5%), or in other words, how easily (elastic) could decision-makers respond to the particular pressure indicator showing a negative trend?
Selection of five 'core' indicators	Imagine that you would have to describe the overall pressure in this policy field using a maximum of five absolutely essential indicators, which five would you choose?

5.5 EU Member States

5.5.1 Denmark

There appear to be no specific criteria for indicator selection in Denmark, however, the availability of information is an important factor (P Krinstensen, personal communication). Indicator selection is currently based on expert judgement, no further details were provided.

The Danish government intends gradually to create a tool for assessing whether environmental objectives may be reached through the measures adopted and whether, as a result of monitoring achievements, it will be necessary to adjust environmental activities (responses). This may be done through the use of indicators, or by development of new models and decision-making methods.

5.5.2 Sweden

Generally accepted criteria as outlined in Section 5.3 and Table 5.1 (OECD) seem to be used by experts involved in indicator development. The experts were mainly scientists from the Swedish EPA, but scientists from universities, and regional and local authorities were also consulted. and in some cases universities and authorities from other countries. The main emphasis at present appears to be on linking indicators to the 18 proposed national environmental objectives and on developing baseline criteria (environmental quality criteria (EQC), see Section 4.4.3) as a basis for suitable indicator selection. In this task the emphasis has recently changed by focusing on the relationship between environmental state and effects on organisms/biodiversity. A preliminary set of EQCs has been sent to regional authorities and other agencies for comment (T. Nilsson, Swedish EPA, personal communication).

The national objectives were chosen according to the following criteria:

- they have defined goals;
- they deal with the most important environmental problems;
- they are of immediate relevance to the present, i.e. deadlines for meeting targets, and
- they reflect a diversity of environments and the diversity of actors concerned.

5.5.3 Germany

The Fraunhofer Institute study (Walz *et al.* 1996 and 1997), aimed at development of a set of environmental indicators for use at Federal level, involved consultation with experts (scientists) in the various fields selected (themes similar to OECD, see Section 4.4.4 and Table A4, Appendix A). Numerous suggestions for indicators (from specialists in the various, relevant disciplines) were taken into consideration, evaluated and selected by expert panels (scientists, economists) on the basis of the following, main criteria:

- ecological soundness (ecological significance for the environmental theme);
- quantifiability and data availability; and
- appropriateness for users (comprehensibility and policy relevance in public discussion).

The importance of the ecological significance as the main selection criterion for indicators was stressed. To this end, a background paper detailing the ecological context of each environmental theme was prepared as a basis.

Comprehensibility of indicators was considered to be a major requirement, but it was recognised that this could not always be achieved. Because of this, it was recommended that an indicator report should not consist of numbers and diagrams, but should include textual explanations and interpretation aids.

International compatibility was taken into account by choosing the OECD (P-S-R) approach as a basis for the German system.

Justifiable expenditure and feasibility of short to medium term implementation of the indicator system was addressed by selecting indicators based on already available data, although some, additional indicators were proposed for future implementation.

To compile the final list of indicators (Waltz *et al.* 1997), a scoring table with five levels was constructed and used to rank the proposed indicators in each theme. This is shown in Table 5.3.

Table 5.3 Scoring table for indicator selection (Walz *et al.*, 1997)

Proposed indicator	Significance for problem area	Quantifiability and data availability	Comprehensibility	Relevance in public debate
xxx	lead indicator	very good	very good	very high
xxx	very important	good	good	high
xxx	important	moderate	moderate	moderate
xxx	less important	low	low	low
xxx	marginal importance	very low	very low	very low

The themes and indicators proposed in the above study, were assessed for their use in presenting the state of the environment of the Federal State of Baden-Württemberg (LfU 1997). Key selection criteria included data availability and quality, focus on the major environmental problem areas, and adequate overall representation of the state of the environment, as well as developments (trends). It was considered particularly important that, wherever possible, data should be available from a single source (consistent methodology) and over several years to allow diagrammatic representation and evaluation in terms of trends.

The development of sustainability indicators at FEST (Diefenbacher *et al.* 1997) was carried out mainly by a team of social scientists and economists, with input from scientists, politicians, local government officials etc. The process involved an assessment of other indicator systems, the establishment of the goals and associated themes, and finally the selection of indicators (restricted to 60) by a process of elimination of the less important indicators. The final draft was submitted for consultation to local and regional interest groups representing Local Agenda 21, environment and ecology, industry, economy and finance, local planning etc.

The recently publicised development of six 'Environment Barometers' for the national assessment of sustainable development, seems to involve wide participation; the programme aims to bring together representatives from around 130 organisations, including local government bodies, environmentalists, industry groups, trade unions, consumer societies, scientists and church groups (ENDS 1998a).

5.5.4 United Kingdom

The UK Department of the Environment, Transport and the Regions (DETR) recognises that, ideally, objectives of indicators are to highlight important issues and possibly influence behaviour within policy makers and environmental experts but also with businesses, local government and general public (HMSO 1996).

The ideal criteria used by DETR to select indicators for sustainable development are given in Table 5.4. However, it is mentioned that in practice it is rare for all criteria to be met. Another criterion is that the package of indicators needs to be as balanced as possible in terms of the coverage and representation of the issues.

Table 5.4 Ideal criteria for indicator selection (HMSO 1996)

- be representative;
- be scientifically valid;
- be simple and easy to interpret;
- show trends over time;
- give early warning about irreversible trends where possible;
- be sensitive to the changes in the environment or the economy it is meant to indicate;
- be based on readily available data or be available at reasonable cost;
- be based on data adequately documented and of known quality;
- be capable of being updated at regular intervals;
- have a target level or guideline against which to compare it.

5.6 Discussion

As with the development of indicator systems on the whole, criteria for the selection of indicators, internationally and nationally, are generally closely based on the criteria used by the OECD, i.e. policy relevance, analytical soundness and measurability.

The overall reliance on the OECD system should provide the advantage of promoting the selection of internationally compatible/comparable indicators.

An important, additional concept for pressure indicators has been introduced by EUROSTAT, namely 'response elasticity', relating to the ease with which responses (actions) can be implemented in practice, i.e. how realistic is the potential for improvement? This could be a useful aid to priority setting, but it could also carry a risk of neglecting important indicators because responses are considered difficult.

Germany has stressed the need for ecological soundness of indicators and has prepared detailed background information for each theme before selecting indicators. This seems to address the need to maintain the links between indicators of the different categories (as emphasised in the closed cycle of the EEA D-P-S-I-R model, Figure 3.4). In addition, the need for comprehensibility (relevance to user) and policy relevance was emphasised.

The main emphasis in Sweden is on the development of 'State' indicators closely linked to national goals, and the development of baseline environmental quality criteria, against which to measure indicators (as ratios), i.e. predominantly Performance Indicators.

In practice, data availability seems to have been the major driving force in indicator selection, although some have proposed additional indicators, for which data are not currently available, for future implementation (Germany). The possible implications of having to generate new data for indicators is clearly a concern in all of the countries studied who all mentioned data availability as one of the key criteria in selecting indicators. Understandably, there is a general reluctance to propose indicators which cannot be applied straight away, particularly in view of the need to collect data over many years in order to assess trends, and the costs involved in setting up and running new monitoring programmes. The emphasis on data availability clearly provides the advantage of facilitating immediate implementation of indicator use, but may detract from the possible need to change data gathering practice and does little to direct and focus future needs.

As far as it has been possible to establish, the main contributors to indicator selection appear to be scientists from academia, research institutes and government bodies, though economists are also involved, and a variety of interest groups are being consulted in some instances, mainly relating to sustainability indicators.

Selection is normally based on 'expert judgement'. Indicator sets have been developed by NERI in Denmark, by the Swedish EPA in Sweden and by the Fraunhofer Institute in Germany. In Germany, panels of experts evaluated indicators according to common criteria and a scoring table was used for the final selection. The widest consultation undertaken was by EUROSTAT who approached 2300 experts from around Europe to initially propose and then prioritise indicators. The approach for selection. None of the countries studied mentioned involvement of the public in indicator selection, although it has been emphasised, particularly in Germany, that indicators should have resonance with the public.

Despite the commonalities in development approach, the indicators developed at the national level vary widely. Although to some extent this reflects the differing environmental concerns and purposes of the indicator systems, in other cases it may be more related to data availability.

6. INDICATORS SELECTED AND THEIR USE

6.1 Summary

Indicators seem to be used primarily for presenting the state of the environment (sometimes including trends) though pressure indicators (e.g. emissions) are often included, whilst response indicators are rarely presented. Consequently, the closed cycle, which is probably the most important aspect of an indicator system, is often neglected.

Moreover, the use of indicators as such is limited, and it is often difficult to distinguish between actual use of indicators (as part of an indicator system) and simply presentation of environmental data in a way which is similar to indicator presentation. Some interesting indicator presentations have been used, for example smiley/neutral/unhappy faces or traffic lights to indicate positive, stagnant or negative trends.

In view of this limited application of actual indicators to-date, it is not possible to assess the extent and means by which policy decisions are based on indicator presentations, or whether any systems in use have proved useful so far.

Clearly, the search for further simplification of indicator systems, for example for dissemination of easily accessible information to the public, is continuing. With this approach there is a risk of oversimplification which may no longer reflect the true situation. Nevertheless, there is clearly a need for this, and it can be valuable, if the simplified system is based on a thorough scientific evaluation of potential indicators, leading to the formulation of a small number of indices, whilst using a wider range of indicators to examine progress on specific topics in more detail.

6.2 Introduction

A wide variety of environmental (and sustainability) indicators have been developed for various purposes, for example

- national status reports;
- performance reports;
- targeting actions;
- evaluating policy impacts and/or investment programmes.

This Section summarises the areas for which indicators have been developed and compares the different uses in the selected Member States.

6.3 OECD and EU approaches

The OECD has published a report which systematically uses the indicator system developed by OECD, presented data for 'Pressure', 'State' and 'Response' indicators as far as possible within the constraints of data availability (OECD 1994).

The first Dobriš report (EEA 1995), produced mainly to assess the overall state of the environment in Europe, reviewed and identified 12 environmental problem areas of particular concern, presenting information on 15 pressures, 11 state issues, and 12 impacts. In accordance with the planned three year follow-up, the second assessment has recently been published (EEA 1998) in order to assess progress towards achieving the European environmental targets (5th EAP). This report again focuses on the 12 environmental problem areas in terms of state indicators and trends. It also identifies the main socio-economic driving forces exerting pressure on Europe's environment and key areas where further action (response) is needed.

The EEA would prefer to produce an annual indicator report with the target group of indicators similar to the Dobriš set of indicators. It is proposed that the report should include nine environmental issues as follows (P Kristensen, NERI, personal communication):

- climate change;
- stratospheric ozone depletion;
- acidification;
- ground-level ozone;
- urban air quality - emission of other air pollutants;
- management of waste;
- inland water resource;
- coastal zones and marine waters;
- nature and biodiversity.

EUROSTAT (1997) published a report on 'Indicators of Sustainable Development'; this was a pilot study applying UN-CSD indicator methodology to the situation in the European Union. The report contains data on economic, social, environmental and institutional indicators. The environmental indicators (seven themes, 21 indicators) represented predominantly driving forces, some responses, and a very small number of state indicators. It was stressed that the purpose of the exercise was not to establish a definitive list of indicators, but to provide an information base, which should be progressively revised and supplemented.

6.4 EU Member States

Over the past years, there have been a number of initiatives for developing national or regional environmental indicators. There appears to be no consensus about any single set of indicators, although most countries appear to have based their current indicators on the OECD core set (see Table A.1, Appendix A). So far few countries have defined impact indicators separately from state indicators. Understandably, the selection of indicators is largely based on already available environmental information and the predominant use of indicators is in the presentation and dissemination of environmental information. Although most countries see the development of indicator systems as an important basis for policy decisions, it is difficult to assess the extent of the actual use of these at present.

The number and types of indicators used vary between countries. Table 6.1 presents an overview of the various environmental themes chosen internationally, by the three selected Member States (for Germany, only those used or proposed at Federal level are included) and the UK. Not all sectors (energy, transport, industry, agriculture, households) are generally covered. The universally covered environmental issues are: climate, ozone layer, acidification, and water resources. Other predominant issues are: biodiversity/landscape, (urban) air quality, waste, and soil degradation. Germany has used additional themes relating to environment and economy, energy, and traffic; and noise, a selection similar to the UK themes, with the exception of noise.

For the two issues selected for a more detailed review in this study, namely climate change and eutrophication, the relevant indicators chosen are listed and discussed in more detail in Section 7.

Table 6.2 summarises the use of indicators in the study countries, including the Nordic group of countries, and the UK for comparison; this is discussed in more detail below.

6.4.1 Nordic Countries

The Nordic Council of Ministers (1997) has published an indicator report on the state of the environment in the Nordic countries (members: Denmark, Finland, Iceland, Norway, Sweden).

The report is based on OECD 'core set' and provides data at Nordic and national aggregation for P-S-R indicators. The issues are the same as in OECD, except biodiversity/landscape is split into biodiversity and cultural landscapes; soil degradation is replaced by agricultural land resources; and general indicators are not dealt with separately.

6.4.2 Denmark

Since 1991, reports on the state of the environment in Denmark have been structured according to the P-S-R framework, presenting information through 55 indicators for eight main environmental issues (MEM 1996). However, with the aim of achieving more comprehensive environmental reports in future, the Ministry of Environment and Energy, and the Danish Statistical Office intend to develop further data and statistics in the area of nature and environmental policy in co-operation with relevant ministries, counties, municipalities and others.

Table 6.1 Indicator issues covered in reports, or under development, in the three selected countries and the UK, compared with OECD and UN-CSD

	OECD (a)	UN-CSD (b)	Dk (c)	Germany (d)	S (e)	UK (f)
Climate change	✓	✓	✓	✓	(✓)	✓
Ozone layer depletion	✓	✓	✓	✓	(✓)	✓
Urban air quality	✓	✓	✓	✓ [1]	(✓) [1]	✓ [1]
Eutrophication	✓	-	-	✓	(✓)	-
Acidification	✓	✓	✓	✓	(✓)	✓
Toxic contamination	✓	✓ [2]	-	✓ [2]	(✓)	-
Urban environmental quality	✓	✓	✓	✓	(✓)	-
Biodiversity/landscape	✓	✓	✓	✓	-	✓
Waste	✓	✓	-	✓	-	✓
Water resources/quality	✓	✓	✓	✓	(✓)	✓
Oceans, seas/coastal areas	-	✓	✓	✓	(✓)	✓
Land resource	-	✓	-	✓	-	✓
Mountain areas	-	✓	-	✓ [3]	(✓)	-
Agriculture and rural development	-	✓	-	✓	(✓)	-
Forest resources	✓	✓	-	✓	(✓)	✓
Fish resources	✓	-	-	proposed	-	✓
Soil degradation (desertification and erosion)	✓	✓	-	proposed	-	✓
Radiation	-	✓ [2]	-	✓	(✓)	✓
Biotechnology	-	✓	-	-	-	-
Environment and economy	-	-	-	✓	-	✓
Environment and energy	-	-	-	✓	-	✓
Environment and traffic	-	-	-	✓	-	✓
Noise	-	-	-	✓	-	-
Leisure	-	-	-	-	-	✓
Mineral resources	-	-	-	-	-	✓
Overseas trade	-	-	-	-	-	✓
General indicators not attributable to specific issues	✓	-	-	✓	-	-

✓ = indicator(s) in use, (✓) = indicators under development, - = no indicator(s)

a) OECD 1994
b) UN-CSD 1996
c) MEM 1996
d) UBA 1995 and Waltz *et al.* 1997
e) SwEPA 1997
f) HMSO 1996

1) air quality in general, rather than urban specifically
2) covered under waste
3) covered under nature

Table 6.2 Summary of the use of indicators in selected Member States

Country/ Organisation	Title	Date of publication	Objectives	Indicators contained
Nordic countries				
Nordic Council of Ministers	Indicators of the state of the environment in Nordic countries (Nordic Council of Ministers 1997)	1997	State of environment to be communicated at regular intervals to decision makers (i.e. status report)	Based on OECD 'core set' ; provides data at Nordic and national aggregation for P-S-R indicators. Issues are the same as in OECD, except biodiversity/landscape is split into biodiversity and cultural landscapes; soil degradation is replaced by agricultural land resources; and general indicators are not dealt with separately.
Denmark				
Ministry of Environment and Energy	Environmental indicator report *(Miljoindikatorer)* (MEM 1996)	1991 and every year	Provide accessible information to the public, giving a national picture (status report) within a global framework , e.g. global warming (CO_2 emissions).	55 indicators covering 7 issues (see Table 5.1)
Ministry of Environment and Energy and Denmark's Statistik	Nature and the Environment in Figures	1990 and 1994 (every 4 years)	Dissemination of environmental information (status/pressures report) and to provide a basis for policy decisions and strategic planning.	Figures and data on the environmental situation and pressures on the environment
NERI/Ministry of Environment	Environment and Society - a review of environmental development in Denmark (NERI 1994)		Dissemination of environmental information (status/pressures report) and to provide a basis for policy decisions and strategic planning.	Description of developments in the state of the environment and the pressures of individual sectors on nature and the environment.
Sweden				
Swedish Environmental Protection Agency	'Progress so far' reports (Ministry of the Environment 1996)	Annually	Examine progress towards achieving national environmental objectives (performance report); Raise public awareness about the need to achieve these objectives	Of 167 national objectives, 9 were selected for examination each year; To simplify the task, the national objectives have been revised to a proposed 18 objectives, and indicators linked to these are under development.

Table 6.2 continued

Country/ Organisation	Title	Date of publication	Objectives	Indicators contained
Germany				
Federal Environment Agency	Daten zur Umwelt (Environmental data) (UBA 1992, 1994, 1997)	since 1984, about every 2 years (latest 1997)	• Summarise the state of the environment (status/trends) • Inform the public • Provide a basis for policy decisions	Does not use indicators specifically, presents a mass of data, but broadly in line with P-S-R indicator system (1997: D-P-S-R)
Federal Environment Agency and Federal Department of Statistics	Umweltdaten Deutschland (Environmental data - Germany) (UBA 1995)	1995	Accessible data (small booklet) for general public (status/trends)	16 themes with 1-14 P-S-R indicators per theme, greatest numbers for air, water and waste (tables, graphical representation of trends, and brief comments/explanations).
Ministry of the Environment and Transport, Federal State of Baden-Württemberg (B/W)	Umweltdaten 95/96 Baden-Württemberg (LfU 1997)	1997 (first time with use of indicators)	• Presentation/dissemination of information on the state of the environment (status/trends) • Form a basis for policy decisions	Includes a section at the end of the report using 16 P-S-R indicators which focus on resources and environmental problems; includes assessment of trends.
AT-BW Stuttgart (funded by Environment Agency B/W)	Report on sustainable development in the State of Baden-Württemberg (output of research project) (Pfister *et al.* 1997)	1997	Presentation of the state of the environment, including trends at regional level (Federal State of Baden-Württemberg) in accessible form to the public (status/trends); Provide a basis for decision-making and priority setting in the context of sustainable development	Selected P-S-R indicators (10 P, 18 S, 1 R) for 11 of the 13 OECD themes plus 'manmade capital' are presented as graphs, usually per capita and per unit manmade capital. Traffic signals are used to illustrate trends (red: action needed; amber: needs closely monitoring; green: ok).
FEST Heidelberg (funded by Environment Agency B/W)	Report on sustainable economic development in Heidelberg and district local/district (output of research project and local pilot study) (Diefenbacher *et al.* 1997)	1997	Assessment of sustainable development at local/district level (Heidelberg and region in the State of Baden-Württemberg) (status/trends)	Environmental aspects are presented through P-S-R indicators (7 P, 4 S, 6 R) for 6 themes: graphs with comments on trends.

Table 6.2 continued

Country/ Organisation	Title	Date of publication	Objectives	Indicators contained
United Kingdom				
Department of Environment	Indicators of sustainable development for the United Kingdom (HMSO 1996)	March 1996	Highlight the main trends and help both policy makers and the public better understand them (status/trends report)	A preliminary set of indicators 21 issues and 120 indicators
Environment Agency	The environment of England and Wales - A snapshot (EA 1996)	April 1996	Form the basis for a fully comprehensive set of environmental data (status and pressures)	Preliminary review of pressures and state of any sector of the environment (16 pressure and 15 state indicators)
Department of Environment	Digest of Environmental Protection Statistics (HMSO 1995)	annually	Presentation/dissemination of environmental information in an accessible form (status and pressures)	Statistics on pressures and states
Scottish Environment Protection Agency	96 State of the Environment Report (SEPA 1996)	1996 (first report)	National overview aimed at protection of the environment	Does not explicitly use indicators, but presents data in a similar form, mainly state, some pressures and responses, for three themes (air, land, water)
Environment and Heritage Service, Department of the Environment for Northern Ireland	Annual Report 1996/1997 (EHS 1997)	1997 (first report)	Report of Activities of the Service (details on implementation of government policy on environment and heritage	Does not use indicators, but presents some information on pressures, state and responses.

NERI National Environmental Research Institute, Denmark
AT-BW Academy for the Assessment of the Effects of Technology Baden-Württemberg, Stuttgart, Germany
FEST Research Institute of the Protestant Churches, Heidelberg, Germany

The above annual report on environmental indicators gives a global picture for some issues and information on the Danish situation specifically. Another environment report, 'Environment and Society (NERI 1994) is followed by a policy document by the Ministry of Environment for each sector/issue, suggesting that indicators may also have been used as a basis for policy development.

6.4.3 Sweden

Sweden does not use 'indicators' as such, although they are currently under development (Olof Swanberg, SwEPA, personal communication). Instead it uses measures and goals to attain the environmental objectives, mainly set in international conventions and agreements and incorporated into the national objectives (previously 167, recently condensed to 18 proposed objectives) of Sweden.

No regular State of the Environment report is produced by SwEPA, but each county is required to report on its progress in meeting environmental objectives, in future, as set out in the county environmental plans (STRAMs). The production of first draft STRAMs has just been completed, and currently these are being examined by SwEPA.

However, Sweden produces an annual report, entitled 'Progress so far', as part of a rolling programme to examine progress made towards meeting the National Environmental Objectives, as required by the government (Ministry of the Environment 1996). The 'Progress so far' reports are used as sources of information by government and parliament. Parliamentary members have used the reports as background information for proposing motions. They are also used to increase public awareness about the need to achieve the National Environmental Objectives.

The programme analyses approximately nine objectives each year. Only relatively few objectives are examined, in part because there is overlap among the large number of objectives, which often have a similar aim and in part due to lack of resources (a reduced number of objectives is likely to be adopted in the near future, see also Section 4.4.3).

Progress is measured via an evaluation approach using information and data collected through interviews, questionnaires, environmental monitoring, official statistics, scientific reports etc., focusing mainly on 'state' and 'response' issues. The data, as well as the measures taken in each sector, are assessed by the different actors involved in meeting the objectives. The instruments used, such as regulatory and financial instruments, are also examined to analyse their effectiveness in combating a problem. Conclusions are based on the judgements of experts.

6.4.4 Germany

National reporting on the environment

Germany has been producing publications on national environmental data approximately every two years since 1984 (UBA 1992, 1994, 1997). The primary purpose of the publication was to provide a summary of the state of the environment and to inform the public, but also to look at trends and to form a basis for policy decisions concerning environmental protection. Even in the earlier reports, the selection and presentation of the data was broadly based on the P-S-R principle, i.e. including:

(i) data on emissions, waste, resource utilisation and productivity;

(ii) environmental quality data to describe the status at the time; and

(iii) data on measures, including the costs of environmental loads and protection, to provide a basis for policy decisions.

Data were not collected specifically for the purpose of producing the report, but were gathered from existing data collected by the Federal Statistics Department, data from ongoing environmental monitoring programmes at Federal level and individual States, results of research programmes, enforcement data (where available and publication permitted), statistics provided by associations and environmental reports of international organisations.

The most recent national report (UBA 1997, Lehmkuhl and Plehn, 1996) broadly uses a Driving Force-Pressure-State-Response Approach, presenting a large amount of environmental data (tables, graphs, cartographic representations, illustrating trends where possible) for each environmental compartment and some problem areas, though the use of indicators is not evident. In fact, the range of data presented has increased since the last report (UBA 1994) and includes a chapter on environment and health. In addition, there is some socio-economic data in order to present information relevant in the context of assessing sustainable development.

A small booklet has also been published (UBA 1995) which has used indicators to summarise the mass of environmental data in a much more accessible, simplified form for the general public. Indicators are grouped into 16 themes, some widely used themes, but with additional themes, such as environment and economy; environment and energy; environment and traffic; and noise (see Table 5.1). The number of indicators used per theme vary from 1 to 14, with the highest numbers covering the themes, air, water and waste. The indicators used in this booklet relating to global warming and eutrophication are discussed in Section 6 of this report.

Research has been carried out in Germany to develop indicators aimed mainly at reporting on the state of the environment, but also for the purpose of assessing sustainable development. The indicators proposed in these projects are summarised below, but have yet to be applied in practice.

Table A.4 (Appendix A) lists the environmental indicators proposed for national use in the Fraunhofer study (Walz *et al.*, 1996 and 1997). The system is based on the OECD system, with some modifications (e.g. more emphasis on resource quality, less on quantity) and the inclusion of an additional theme, radiation (a total of 14 themes). In total, about 140 indicators were selected; of these, after evaluation based on data availability and quality, about 100 were considered feasible for application in the short to medium term.

Improvements were made, compared with the OECD system, in the theme of toxic contamination which is characterised by a particularly large number of relevant individual substances. An approach was developed which aggregates information input of a large number of individual substances into an overall pressure index using ecotoxicological expertise.

Consequently, the indicators represent a greater information input than that suggested by the small number of individual substances covered in the OECD system (Walz *et al.* 1996).

An interesting feature of the scheme is the reference to links with other environmental issues or indicators, where appropriate, for example global warming linked to energy usage. This approach was recommended by the development team, particularly for use in environmental reporting (Walz *et al.* 1996).

The system was primarily aimed at the national level. As in the OECD approach, a sectoral subdivision (disaggregation) of pressure indicators was envisaged, but not attempted as part of the project which was to provide a broad framework as a basis for further development. The question of the degree of aggregation of the environmental indicator system was left open, although promising starting points for aggregation between individual problem areas were identified for consideration and further study.

The system of environmental indicators proposed by workers at the Wuppertal Institute, and focusing on a precautionary, resource-oriented approach in the context of sustainability, is outlined in Table 6.3 (Loske and Bleischwitz 1996). This scheme offers a high degree of simplicity with highly aggregated indicators and the possibility of application at any spatial level (national, regional, local).

Indicators at regional, district and local level

The State of Baden-Württemberg has been particularly active in promoting research, and has been the first Federal State in Germany to apply the use of indicators in reporting on the state of the environment.

a) Landesanstalt für Umweltschutz (LfU), Baden-Württemberg

Following an evaluation of the themes and PSR indicators proposed in the Fraunhofer study and other indicator systems, 16 indicators were selected as the most representative and available for immediate application (on the basis of data availability and reliability) in the State of Baden-Württemberg (Oelsner 1997), and for providing an overall indication of developments in the environmental situation. These indicators (6 P, 5 S, 5 R) covered the themes water, waste, land use, acidification, global warming, and environmental protection (response: spending).

Whilst the main part of the report comprised a large amount of data, in terms of environmental compartments (air, soil, water) and several problem areas (e.g. traffic, noise, waste, radioactivity), the final chapter used the environmental indicators to summarise the state of the environment in Baden-Württemberg.

Graphs showing developments are shown for each indicator, including data from 1977 where possible (from 1974 for water quality) up to 1995 or the most recent, available data. A brief explanation was given for each indicator, as well as an assessment of the trend according to the categories, positive, stagnating/constant, and negative (in terms of environmental quality developments.

Table 6.3 Precautionary, resource-oriented system of environmental indicators proposed by Loske and Bleischwitz (1996) at the Wuppertal Institute (Germany).

Resource usage	**Material** • material consumption (Mt/a) • Proportion renewable resources (%)	**Energy** • Primary energy consumption (PJ/a) Proportion renewable energy resources (%)	**Water** • Water abstraction (1000 M m^3/a) • Proportion of groundwater abstraction (%)	**Surface** • Increase/decrease in built-up area (%/a) Increase/decrease in uncarved (by roads, rails etc.) surface area (%/a)
Selected compound emissions	CO_2, SO_2 . NO_2, NH_3, Volatile organic carbon compounds, Synthetic fertilisers, Pesticides.			
Pressure indices	Global warming potential, Ozone depletion potential, Acidification potential, Eutrophication potential, Toxicity index (under development).			

As in the national reports, the publication of information on the state of the environment was the main purpose of issuing the report. However, the need was stressed for summarising the mass of information in a form which would provide a meaningful overview (i.e. the section on indicators), and could, therefore, form a basis for policy decisions. Since this was the first time the indicator system was applied to present environmental information (status/trends), it is too early to assess its influence on policy decision-makers.

b) Akademie für Technikfolgenabschätzung (AT-BW)

As discussed earlier (Section 4), AT-BW undertook a study to develop indicators for sustainable development in the State of Baden-Württemberg (Pfister *et al.* 1997).

The sustainability themes selected in this study are broadly in line with the OECD system and the Fraunhofer proposal (Tables A1 and A4, Appendix A), with the omission of urban environmental quality, fish, radiation, and general, which were not considered highly relevant to Baden-Württemberg. Added themes were man-made capital and imported, non-renewable resources. The number of indicators selected was considerably smaller than those proposed in the OECD system, i.e. a total of 29 indicators (10 P, 18 S, 1 R).

As part of this study, the academy published a report using the themes and associated indicators selected (Pfister *et al.* 1997). One of the selected categories, biodiversity/diversity of landscapes and ecosystems, was omitted due to inadequate data availability. The data were presented in an attractive form that is easily assimilated and understood (see example pages in Appendix B).

For each indicator, graphs were presented in terms of actual values or proportions and in terms of these per man-made capital per capita. The trends were assessed taking into account both forms of representation, sometimes offsetting losses of natural resources against increases in man-made resources, if the latter significantly outweighed the former. The trends were valued in each category or set of indicators in terms of positive, unsure/critical and negative (similar to the environmental data report issued by the LfU for the State of Baden-Württemberg). These values were graphically presented by means of traffic lights, whereby a:

- negative sign (red light) = unsustainable: response/action necessary;
- neutral sign (amber light) = direction uncertain/critical, close monitoring needed; and
- positive sign (green light) = trend in the direction of sustainable development.

An explanatory note was provided with each presentation, giving the reason for assigning the particular trend value.

The aim of the report was the presentation to the public of the state of the environment, including trends, in an accessible form. In addition the report is expected to form a basis for political initiatives and measures, and contribute to decision-making involving the setting of priorities. However, it is too early to determine how this will be implemented. Moreover, it was recognised that further research and application of the system of indicators, may result in adjustments to the selection for future presentations, and the need for flexibility was stressed.

d) Forschungsstätte der Evangelischen Studiengemeinschaft (FEST)

The project developed at FEST was specifically designed to be applied at local/district level, focusing on sustainable development (see Section 3). The system proposed in this study includes six categories in each of the main aspects, environment, economy and sociological, with three indicators in each category (in total 7 P, 5 S, 6 R). An additional category was proposed with indicators specifically adapted to the local situation.

The system was tested for the town of Heidelberg and the district Rhine-Neckar and a report presented. Graphs showing the available time series (no data for two indicators) were presented, including textual explanations and interpretations in terms of sustainabilty, for each indicator, and a summary for each category. The proposed categories (6) and indicators (18) were used, covering 1960-1995 where data were available (Diefenbacher *et al.* 1997).

6.4.5 United Kingdom

Ideally, objectives of indicators are to highlight important issues and possibly influence behaviour within policy makers and environmental experts but also with businesses, local government and the general public (HMSO 1996).

To achieve this, some indicators have been included which will be of interest to certain groups - individuals, householders, etc. so that they can see the impact their own activities have on sustainable development. This can be done by breaking down some of the pressure or impact indicators by sectors and expressing them where possible in units to which individuals can relate - for example, per capita or per household rather than national aggregates (HMSO 1996).

In the report Snapshot (EA 1996), information on the environment has been presented following the Pressure and Status framework, 16 pressures and 15 status have been identified.

There are other publications of information on the pressures placed on the environment in England and Wales and on the resulting state. For example, statistical data are collated annually by the Department of the Environment and published in their Digest of Environmental Protection Statistics (HMSO 1995). This covers nine main issues.

In Scotland and Northern Ireland, indicators have not been used explicitly in the state of the environment report (SEPA 1997, EHS 1997) but indicators are being developed in Scotland by a working group made up of representatives from a wide range of organisations with environmental interests. The key aim is to identify indicators which support policy needs rather than relying on existing information. A report is due for publication and it is likely that it will suggest 50-60 indicators.

The Department of the Environment, Transport and the Regions (DETR 1997) has identified the following key issues which indicators should be used to address:

> "Indicators should have a high profile - to be reported on the 6 o'clock news, should be used to help set targets and to monitor and report progress towards them, tailored to reflect what we want to achieve and for different audiences."

6.5 Discussion

Indicators seem to be used primarily for presenting the state of the environment (sometimes including trends). The most widely used indicators are state indicators. There are fewer pressure indicators and very few response indicators as these appear to be more difficult to define or data are not available.

Indicators of all categories of an entire, coherent system (e.g. P-S-R or D-P-S-I-R) are rarely presented as such. Even where, for example, Pressure, State and Response indicators are presented for a particular theme, they are often not directly related. Consequently, the closed cycle, which is probably the most important aspect of an indicator system is often neglected. This may, in part, be due to lack of data to present all categories, or partly due to the need to restrict the amount of data to be presented.

Moreover, the use of indicators as such is limited, and it is often difficult to distinguish between actual use of indicators and simply presentation of environmental data, since the development of indicators, on the whole, is largely based on the use of already available data; this is often summarised in a way which could be regarded as a presentation of indicators, although it is not explicitly stated as such, and rarely complete in terms of an indicator system.

In view of the limited application of indicator systems to-date, it is not possible to assess the extent and means by which policy decisions are based on indicator presentations, or whether the systems in use have proved useful so far. Only future developments and applications of indicator systems may be able to demonstrate this aspect.

Clearly, the search for further simplification of indicator systems, for example for dissemination of easily accessible information to the public, is continuing. With this approach there is a risk of oversimplification which may no longer reflect the true situation. Nevertheless, there is clearly a need for this, and it can be valuable, if the simplified system is based on a thorough scientific evaluation of potential indicators, leading to the formulation of a small number of indices to truly reflect the situation. In addition, a wider range of indicators should be used to examine progress on specific topics in more detail.

Although indicators have been put forward as a tool to both monitor performance of existing policies and to influence future policy making, in practice, their use seems to be limited to reporting on the state of the environment. Although stated as an aim of the indicator systems, few countries could demonstrate feedback into policy formulation. Denmark is probably the most advanced towards this approach; thus for example the government will, in 1998, assess the effect of industry-orientated initiatives at reducing CO_2 emissions and will establish the CO_2 goal deficiency. Policy adjustments will be made to ensure that target reductions are achieved.

Some interesting approaches to presenting indicator results have been adopted, for example:

- trend positive (decreasing emissions - represented by a smiling face), negative increasing emissions - unhappy face), neutral (no change - neutral facial expression) approach adopted by the Nordic Council; and

- traffic light system for sustainable development indicators in a regional report in Germany, where a red light indicates a negative, unsustainable trend; an amber light, stagnant position which must be kept under close watch; and a green light represents a positive, i.e. sustainable, trend.

7. COMPARISON OF INDICATORS

7.1 Summary

Two topics, Global Warming and Eutrophication, have been selected for more detailed analysis of the use of indicators in the countries studied. In general, the indicators for Global Warming were more consistently used than those for Eutrophication. Eutrophication is not identified in all countries as a specific theme; instead, the issue is covered under Water Resources/Quality.

In relation to Global Warming/Climate change, CO_2 emission is the most widely used indicator, whilst Nitrogen and Phosphorus emissions and concentrations in water are mainly used in relation to Eutrophication. In both cases, response indicators are less well defined and used at this stage.

A closer study of indicator use for these two issues has shown that completely unrelated indicators are often used for a given issue; this means that it is not possible to assess the impact of pressures or responses on the state of the environment. Moreover, the study has shown that a wide variety of indicators are used: even where the indicators appear to be similar, they are expressed in different ways, and may include or exclude certain contributions (sectors); this makes meaningful comparisons at international or global level difficult.

The Nordic Council is attempting to standardise indicators, and NERI in Denmark is undertaking studies to identify causal links between potential indicators in the area of eutrophication.

7.2 Global Warming

7.2.1 Background

The greenhouse effect is a natural phenomenon whereby gases in the atmosphere absorb radiation reflected by the earth. This process maintains the surface temperature within a range suitable for life. The composition of the gases is important in determining the amount of radiation absorbed and hence the temperature maintained. The most important gas is water vapour followed by carbon dioxide (CO_2), other gases include methane (CH_4), nitrous oxides (NOx), trophospheric ozone and fluorinated gases (CFCs).

There are concerns that this natural phenomenon has been enhanced since the industrialisation, resulting in more heat being absorbed and, consequently, leading to global warming and climate change (e.g. changes in wind systems and precipitation, rise in sea levels, displacement of climatic zones).

The following broad generalisations can be made about indicators for global warming:

Driving Forces: Industrialisation leading to an increase in emissions of gases which contribute to global warming.

Pressure: The key pressure is primarily anthropogenic emission of CO_2 from combustion of fossil fuels. CO_2 is not the most efficient gas at absorbing radiated heat but it is the most significant as it has the highest emissions and highest concentrations in the atmosphere. Carbon is naturally cycled through the atmosphere, plants, soil and oceans through processes such as respiration, photosynthesis and chemical diffusion. Anthropogenic emissions have been estimated to contribute only 3% of the natural exchange but may, nevertheless, influence climate change. Hence, the main Pressure indicator is anthropogenic emission of CO_2.

State: The main state indicators are concentrations of CO_2 and other gases in the atmosphere.

Impact: The main impact indicators are measures of effects resulting from the environmental state, such as climate change resulting in, for example, changes in temperature, higher sea levels, increased flooding and changes in ecosystems (e.g. changes in vegetation distribution zones) and agricultural production.

Response: The main response indicators measure the effectiveness of the policy response to tackle the main pressures. In this case, reduction in use of fossil fuels, and increases in non-fossil fuel alternatives as a proportion of total energy use.

The United Nations Convention on Climate Change was opened for signature at the Earth Summit in Rio de Janeiro in 1992. One of the core elements is the industrialised countries' obligation to stabilise emissions of greenhouse gases by the year 2000 in relation to 1990. The EU has adopted a corresponding target for the EU's total CO_2 emissions and all study countries have set targets for reductions in CO_2 emissions.

The UN Convention also requires simultaneous preservation of CO_2 sinks, such as forests, but appropriate indicators do not yet appear to have been set at national level.

Most countries appear to have based their current indicators on the OECD core set and therefore adopt a P-S-R approach, though with the main emphasis on pressure indicators for this particular issue. Table 7.1 summarises the indicators used or proposed internationally and nationally in the study countries (see also Appendix A for detailed listings of indicators proposed by the OECD, UN-CSD and German research project). Although based largely on the P-S-R approach, they include a few impact indicators relating mainly to global temperature. The most commonly adopted indicator so far appears to be the pressure indicator, CO_2 emission, and the state indicators, CO_2 or greenhouse gas concentrations, whilst response indicators are not widely used.

The use of indicators appears to be closely related to data availability, i.e. response indicators are likely to be introduced in the medium to long term only. Some countries appear to be using achievement of CO_2 emission targets as a response indicator Nordic countries, Germany).

Table 7.1 Summary of pressure, state (S) and impact (I), and response indicators proposed or used for global warming internationally and in study countries

Indicator	OECD (a)	UN-CSD/ SCOPE (b)	EEA/ EUROSTAT (c)	Nordic States (d)	Dk (e)	S (f)	D (g)	UK (h)
Pressure indicators								
CO_2 emissions	✓	(✓)[1]	✓	✓[1),2)]	✓[1),3)]	✓[1),3)]	✓	✓[3)]
CH_4 emissions	-	-	✓	-	✓	-	✓	✓[3)]
Index of total greenhouse gas emissions	(✓)	(✓)	✓	-	✓	-	✓	✓[2)]
N_2O emissions	✓	-	-	-	✓	-	✓	-
CFC emissions/use	✓	(✓)	-	-	✓	-	✓	-
State (S) and Impact (I) indicators								
Atmospheric concentrations of CO_2 (S)	-	-	-	✓	✓	-	✓	-
Atmospheric concentrations of green house gases (S)	✓	-	✓	-	✓[4)]	✓[4)]	✓	-
Global greenhouse gas radiative force (S)	-	-	-	-	-	-	(✓)	✓
Global mean temperature (I)	(✓)	-	✓	✓	✓	-	(✓)	-
Global temperature change (I)	-	-	-	✓	✓	-	-	✓
Response indicators								
Energy efficiency	(✓)	-	-	-	-	-	(✓)	✓
Energy intensity	✓	-	-	-	-	-	✓	-
Proportion of fossil fuel consumption	-	-	-	✓	✓[4)]	✓[4)]	-	-
Expenditure on air pollution abatement	-	(✓)	✓	-	-	-	-	✓
Economic and fiscal instruments	(✓)	-	-	✓	✓[4)]	✓[4)]	(✓)	-

✓ indicator used, (✓) proposed, - not used/proposed
1) also per capita, 2) also per unit GDP, 3) also by source.
4) contribution to Nordic Council report

a) OECD 1994
b) UN-CSD 1996, SCOPE 1994
c) EEA 1995, EUROSTAT 1997
d) Nordic Council of Ministers 1997
e) Nordic Council of Ministers 1997, MEM 1996, NERI 1994
f) Nordic Council of Ministers 1997
g) UBA 1995 and Waltz *et al.* 1997
h) HMSO 1996, EA 1996

Dk: Denmark
S: Sweden
D: Germany

7.2.2 Nordic Countries

Emissions of CO_2 are used by the Nordic Council of Ministers (1997) in its report 'Indicators of the State of the Environment in Nordic Countries'. The figures are presented as a Nordic total and, separately, for the different Nordic Countries (Denmark, Finland, Iceland, Norway, Sweden). Trends in emissions of CO_2 are presented graphically as indices using 1988 as a baseline, but data are available for all, except Denmark, before this time. Data from 1980, 1990 and 1994 are compared in terms of tonnes CO_2, and tonnes CO_2 per capita and, for 1994, as emissions per unit of GDP (kg per US$). Indicators are characterised as positive (decrease in emissions), negative (increase in emissions) or neutral (no overall change) and have a brief description explaining this. The indicator was negative in all countries, except for Sweden where it was neutral, with a 23% decrease in emissions since 1980 but an upturn in recent years. Emission figures are not adjusted for climate fluctuations, nor for electricity imports/exports, although this is done for those provided to the Intergovernmental Panel on Climate Change (IPCC).

In the same report, the state indicator, atmospheric concentration of CO_2 is presented graphically from 1800-1994 (provided by IPCC); and the impact indicator, changes in global mean temperature for the period 1856 -1995 (from University of East Anglia and Norwegian Meteorological Institute), is presented graphically in relation to the normal value for the period 1961-1990. This is supplemented by assessments made by IPCC.

Fossil fuel consumption as a percentage of total energy consumption is used as a response indicator. This is shown for each country separately, and as a Nordic total, and trends are presented graphically as an index against 1976. Total energy use includes the following energy sources: nuclear, hydropower, energy from waste, solar energy, wind energy, bioenergy, fossil fuels; and includes the use of energy sources as raw materials in other manufacturing industries but omits energy consumption in transport and the use of crude oil or natural gas for transformation/conversion (e.g. petrochemical industries or refineries).

All Nordic countries have ratified the UN Convention on Climate Change, and goals for reductions in CO_2 have been set nationally. The Nordic Council of Ministers (1997) therefore use national CO_2 emissions compared to national goals established under the UN convention as a broad indicator to measure progress towards goals, these are not, however, combined into a Nordic total.

A CO_2 tax has been introduced by all Nordic countries, except Finland, as one instrument to achieve their goals of reductions in CO_2 emission; hence, gasoline prices (US$ per litre) for different countries (EU and world-wide) together with the percentage of this as tax, and the percentage which relates to CO_2 tax, are presented as a policy feedback indicator.

7.2.3 Denmark

Denmark regularly supplies information on indicators to the Nordic Council of Ministers. National data are provided as emissions of CO_2 per capita, and CO_2 emissions by sector/sources, such as biogas, natural gas, petrol and coal. Indicators were also reported in a national environmental indicators report, *Miljo indikatore* (MEM 1996). CO_2 emission is the principal pressure indicator used to monitor climate change in Denmark. In the 1996 report, the data are presented graphically in their global context, namely:

- trends (from 1860 to 1995) in emissions of CO_2 for four energy sources (tonnes per annum for biogas, oil, coal and natural gas) provided by the Danish Technical University; and

- CO_2 emissions per capita (tonnes per annum) for different countries/continents (data provided by European Commission/DG17).

National trends (from 1975 to 1995) on CO_2 emissions for six sectors (industry, transport, etc.) were also presented graphically.

The state of the environment in Denmark 1994 report (NERI 1994) presented a global picture and a summary of the estimated total Danish emissions per sector, for the most important greenhouse gases (CO_2, CH_4, CFC-11 and CFC-12) in 1989 (expressed in tonnes per year). Total emissions from both natural and anthropogenic sources have only been estimated for CO_2 and CH_4. It also referred to the energy sector where graphics were used to compare the following:

- world energy consumption and CO_2 emissions (as an index compared to the 1950 level, or expressed per capita; data submitted by World Resources Institute); and

- trends in energy consumption, and emissions of NOx, CO2 and SO2, in Denmark for the period 1972-92 (source Danish Energy Agency).

State indicators were also presented graphically in the environmental indicators report in a global context, such as trends in global CO_2 concentration (tonnes per annum from 1860 to 1995 provided by Energistyrelsen) and increase in global mean temperature from 1860 to 1995 (provided by Danish Technical University).

The NERI report (NERI 1994) included impact indicators such as change in Earth's temperature since 1850, expressed as deviation from the mean temperature for the period 1951-1980, and change in temperature in Denmark over the last 100 years, expressed as both annual mean and sliding 20 year mean. The report also presented trends in the global atmospheric concentration of the most important greenhouse gases (CO_2, CH_4, N_2O and CFC-11) (source IPCC).

Denmark has set a national goal of a 5% reduction in CO_2 emissions by the year 2000, compared to the 1990 level, and by 20% by 2005, compared to the 1988 level. Performance against these goals is used as a response indicator.

The authors of the NERI report pointed out that the Danish targets for reducing CO_2 emissions did not take into account the additional CO_2 uptake in biomass that can be expected from the expansion of forest areas; the latter is likely to be doubled, following an EU decision to reduce agricultural land usage. How this will be taken into account in terms of pressure and response indicators appears still to be determined.

7.2.4 Sweden

Although Sweden has been active in developing indicators at a European and Nordic level, it does not currently appear to use these at a national level. However, it does present information on energy consumption in its OECD environmental performance review (OECD 1996). ENDS (1997) reported that, between 1990 and 1996, Sweden's CO_2 emissions rose by 8% because dry winters reduced the hydropower available. This situation could be exacerbated further with the current government's policy commitment to phase out nuclear power. Moreover, if fuel used in international shipping and aviation is taken into account, Sweden's CO_2 emissions rose by 15% between 1990 and 1996.

7.2.5 Germany

National (Federal) level

A booklet published by the Federal Environment Agency (UBA 1995) presented P-R-S indicators, in broad terms, to summarise environmental data in a form more readily accessible to the public than the comprehensive reports on the state of the environment. Under the theme 'climate', CO_2 emissions (1980, 1985, 1987, 1990) were presented and compared with international data. Other greenhouse gas emissions (CH_4, N_2O) and those indirectly affecting climate (NO_x, volatile organics and CO) were also presented. Other relevant indicators or more details were presented under the theme 'ozone layer' (CFCs), 'air' and 'environment and energy', but no overall assessment of trends was made. In addition, the state indicator, CO_2 concentrations in the atmosphere was presented from 1975 to 1993, noting an average annual increase of 1.5 ppm.

The summary environmental indicator booklet (UBA 1995) also presented total energy consumption (1990-1993), primary energy consumption (industry and vehicles, 1980-1993) and energy intensity per capita (1980-1991). All showed positive trends (decreases in consumption) which were mainly attributed to greater energy efficiency and increase in nuclear fuel use. However, primary energy consumption by vehicles increased, whilst usage by industry decreased. Energy intensity showed a 21% decrease from 1980-1991 for the former West Germany.

The Annual Report of the Environment Agency (Lehmkuhl and Plehn, 1996) illustrated the development of primary energy consumption linked to CO_2 emission. On the whole, both decreased over the period 1990 to 1996, although a slight increase was apparent in 1996 compared with 1995 (possibly accounted for by the cold winter of 1995/96). Attempts were made to aggregate the large number of possible responses into a smaller number of main responses and, on this basis, project the resulting, altered trends.

International programmes on climate protection, such as the UN resolution, are supported by Germany. A programme was established in 1990 and is continuously being updated and refined. The government has set a target of 25% reduction in CO_2 emission by 2005, compared with 1990 (Lehmkuhl and Plehn, 1996). Specific measures to reduce 'green house gas' emissions are still being planned and currently include 130 decided or planned measures. To monitor progress towards achieving the target, the gathering and presentation of data is considered a high priority. In addition, further developments and application of energy conservation measures and use of renewable sources of energy are given high priority, and the introduction of economic instruments, designed to promote energy conservation and reductions in CO_2 emission, is likely. Response indicators are still under development and likely to be introduced as data become available (see below, research project: Walz *et al.* 1997).

Research projects for indicators for national use

For national use, Germany has proposed a CO_2 index (Global Warming Potential - GWP) based on emissions of CO_2, CH_4, N_2O, and production of CFCs and halons, all calculated as CO_2 equivalents (Walz *et al.*, 1997). Similar to the OECD system, the use of individual gas emissions was also proposed; these are more comprehensive than the OECD selection, comprising CO_2, CH_4, N_2O, CFCs 11, 12, 13, 22, 113, 114, and 115, halon 1211, 1301 and 2402, carbon tetrachloride, and methyl chloroform. In addition, CFC substitutes and the usage of CFCs and halons were proposed for medium to long term use. The proposed indicators were also linked to energy consumption (response indicators only).

In addition, the following state indicators were proposed: atmospheric concentrations of CO_2, CH_4 and N_2O, global mean temperature. In the long term, it was proposed to add the sustainability indicator of radiative forcing.

The response indicators proposed for national use (Walz *et al.*, 1997) are as follows:

- Fulfilment of the CO_2 reduction target (fulfilment of 25% reduction in emission by the year 2005, compared with 1990);
- Financial support for renewable energy usage and energy conservation measures (medium term);
- Energy usage for domestic heating (per m^2);
- Average efficiency of electric power production;
- Average energy usage of passenger vehicles.

In addition, it was recommended to refer to related indicators, such as measures to reduce CFC production (CFC-11 equivalents) and fertiliser applications.

In contrast, the Wuppertal Institute (Loske and Bleischnitz, 1996) proposed the use of highly aggregated pressure indicators only. This focused on a precautionary, resource oriented approach (without geographical limitation), proposing the use of the pressure index 'global warming potential', as well as CO_2 emission, and energy consumption in terms of primary energy and proportion of renewable energy.

However, the latter two studies have not been implemented to-date, in part this may be due to a lack of the relevant data.

Regional (individual Federal State) level

The Federal State of Baden-Württemberg made use of indicators for the first time in its latest report on environmental data issued by the Ministry of Environment and Traffic (LfU 1997) and in the report on sustainable development issued by the Academy on Effects of Technology (Pfister *et al.*, 1997). Graphical presentations are provided in both of these and trends are characterised as positive (decreasing emissions), negative (increasing emissions), or stagnant (no overall change). The report on sustainable development by Pfister *et al.* (1997) presents the conclusion by means of traffic signals, i.e. red light: negative trend - unsustainable; amber light: stagnant - must be kept under close watch; and green light: positive trend - sustainable.

The environmental data report (LfU 1997) included the pressure indicator, CO_2 emission, the related indicators, primary energy consumption, and the response indicator, energy efficiency, although the latter were mainly used to assess the trend in resource depletion. CO_2 emission was presented for the period 1977 to 1994, and the trend was considered to be stagnant, with 1994 levels having returned to 1990 levels after an increase in the intermediate period. The trend in primary energy consumption was considered stagnant, whilst energy efficiency was negative.

In contrast, the presentation on sustainable development (Pfister *et al.*, 1997), which took into account CO_2 emission and CO_2 concentration (pressure and state) (data from 1972 to 1994), both in terms of actual and per man-made resource per capita, concluded that the trend was not sustainable (negative trend - 'red traffic light').

No response indicators were used in the above two indicator presentations, focusing instead on pressure and/or state indicators.

7.3 Indicators for Eutrophication

7.3.1 Background

Eutrophication is a natural process of nutrient enrichment of waters and a consequent increase in plant production and organisms dependent on them. This process normally takes many hundreds of years but anthropogenic inputs of nutrients, such as nitrogen and phosphorus, can result in rapid growth of algae and plants. The system may become unbalanced, with more plant material being produced than consumed, and algal blooms and nuisance growths of aquatic plants can result. These may cause a visual nuisance, reduced transparency and taste and odour problems (in freshwaters used for drinking water production); it can result in a decline in fisheries and present a health hazard if the algae release toxins. When the algae and plants decompose, it can result in oxygen depletion, and consequent damage to fish spawning grounds and direct fish kills.

In marine waters, eutrophication may impact on fisheries, shell-fisheries and water-based recreational activities and tourism. In freshwaters this may impact on sport and commercial fisheries, navigation, drinking water supply and water-based recreational activities and tourism.

Within the EU the severity of the eutrophication problem varies. In most Member States it is a localised, but sometimes significant problem which can impact on drinking water supplies.

However, in Denmark, Italy and the Netherlands it is a serious problem affecting both coastal areas and inland waters.

Driving Forces: The main driving forces are intensive agricultural production resulting in overuse of fertilisers or excess production of manure, as well as increased population pressure resulting in increased domestic sewage, and increased use of phosphates in detergents and their release to watercourses via sewerage systems.

Pressure: In general terms phosphorus (P) is the nutrient limiting the growth of algae and plants in freshwaters, whereas nitrogen (N) is the limiting nutrient in saltwaters. The most important sources of these nutrients are agriculture (commercial fertilisers and manure) and domestic sewage, although industry, fish farms and pollutants (e.g. nitrogen compounds) may also represent important sources. Premazzi and Chiaudani (1992) estimated that point sources accounted for more than 70% of the total P load in EU inland surface waters, of this 40-50% was detergent phosphate. Diffuse pollution from agriculture represented an average of 17% of the total P load, although this was up to 30% for Ireland. Pressure indicators, therefore, tend to reflect total discharges of N and P or surplus produced/used in agriculture.

State: The main indicators are N and P levels, and oxygen depletion or the potential for oxygen depletion (e.g. biological/chemical oxygen demand, BOD/COD).

Impact: Biological impact indicators may relate to the presence of nuisance growths of algae or toxic algal blooms, changes in distribution of algae or plants and fish kills resulting from oxygen depletion.

Response: The main indicators in use appear to relate to the extent populations are connected to sewers, and tertiary treatment in waste water treatment plants (N removal for marine waters). There do not appear to be any indicators in active use to measure the effectiveness of policies reducing nutrient inputs from agriculture.

Most countries appear to have based their current indicators on the OECD core set which is shown in Appendix A (Table A1). Pressure, state and response indicators used or proposed internationally and in the different study countries are summarised in Table 7.2 and considered in turn below. So far few countries have defined impact (I) indicators separately from state indicators; these are therefore considered together with state indicators.

The Swedish EPA has recently undertaken a study with the European Environment Agency (EEA/SwEPA 1997) which attempts to summarise 'environmental state indicators' used by different Member States; in this a large number of state and impact indicators arc listed for different types of environments. However, the study appears to include any parameters measured or proposed for use as indicators, not just indicators as such. Consequently these are not discussed further in this report, unless they are used as indicators specifically.

Table 7.2 Summary of P-S-(I)-R indicators used or proposed for eutrophication internationally and in the study countries

Indicator	OECD (a)	UN-CSD/ SCOPE (b)	EEA/ EURO-STAT (c)	Nordic States (d)	Dk (e)	S (f)	D (g)	UK (h)
Pressure								
N and P emissions to water and soil	(✓)	(✓) 3)	-	✓ 1)	✓	✓ 5)	✓ 1) (✓) 2)	✓ 1)
N from fertiliser use and livestock	✓	-	✓	-	-	-	✓	-
P from fertiliser use and livestock	(✓)	-	✓	-	-	-	✓	-
Fertiliser use	-	(✓)	✓	-	-	-	✓	✓
Surplus N and P in fertiliser/manure	-	-	-	✓ 2)	✓ 5)	✓ 5)	(✓)	-
Nutrient balance on agricultural land	(✓) 3)	-	✓ (N)	-	-	-	(✓) 4)	-
Detergent load	-	-	-	-	-	-	✓	-
State								
BOD/DO or COD	✓	(✓)	✓ 2)	-	-	-	-	-
N and P conc. (inland waters, marine waters)	✓ marine 3)	-	✓ 2)	✓ 2) (✓) 1)	✓	✓ 5)	✓	✓
Actual/critical load balance of nitrogen deposition in forest areas	-	-	-	-	-	-	(✓)	-
Distribution of selected weeds (marine)	-	-	-	✓	-	-	-	-
Phytoplankton bio-mass (I)	-	-	-	-	-	-	✓	-
Eutrophication (I)	-	-	✓	-	-	-	-	-
Response								
Population (%) connected to biological and/or chemical sewage treatment plants	(✓)	-	-	✓	-	✓ 5)	✓	-
Population (%) connected to sewage treatment plants	✓	(✓)	✓	-	-	-	✓	-
User charges for waste water treatment	(✓)	-	-	-	-	-	-	-
Market share of phosphate-free detergents	(✓)	-	-	-	-	-	-	-
Measures for the reduction of fertiliser use		-	-	✓	✓ 5)	✓ 5)	(✓)	-

✓ used (✓) proposed

1) coastal/marine 2) inland 3) long-term 4) medium-term 5) for Nordic Council report
BOD: Biological Oxygen Demand DO: Dissolved Oxygen COD: Chemical Oxygen Demand

a) OECD 1994
b) UN-CSD 1996, SCOPE 1994
c) EEA 1995, EUROSTAT 1997
d) Nordic Council of Ministers 1997
e) Nordic Council of Ministers 1997, MEM 1996, NERI 1994
f) Nordic Council of Ministers 1997
g) UBA 1995, Waltz *et al.* 1997
h) HMSO 1996, EA 1996

Dk: Denmark
S: Sweden
D: Germany

7.3.2 Nordic countries

Separate indicators are used for inland and marine waters to measure the State of the Environment in Nordic Countries (Nordic Council of Ministers 1997).

The pressure indicator for inland waters is the net supply (surplus) of nitrogen and phosphorus in commercial fertiliser and manure. Information on surplus supply of N and P is given separately for each country and as a Nordic total. Trends are shown graphically using relative indices compared to 1988. Figures are given both as surpluses in tonnes and as tonnes per area of agricultural use (tonnes/km^2). Surplus supply is defined as total supply minus N and P removed by crops. N figures are adjusted for ammonia (NH_3) losses, and unit area figures are calculated for agricultural land in use; this includes arable land, gardens, permanent meadows and pastures (the N and P levels for Iceland are relatively high, partly because N and P is also spread on reclaimed land, yet only arable land is considered in the Icelandic figures). The N figures for Denmark include soil fixation and atmospheric deposition. P surpluses are calculated on a routine basis for Denmark. Finland and Iceland have positive trends (decreases) for both N and P. Sweden and Norway have positive trends for P, but Denmark, Norway and Sweden all have negative trends (increases) for N.

The pressure indicators for marine waters are total discharges of N and P. Nitrogen is considered the most important indicator, but the nitrogen/phosphorus ratio is also important because this affects the species composition of planktonic algae. Eutrophication is not considered a problem in Iceland because currents and turbulence around its coast ensure renewal and mixing; it does not, therefore, us a marine indicator. In Southern Scandinavia nitrogen inputs to the sea from arable areas are double that from all point sources. Total inputs are calculated as those from both riverine sources and direct discharges. Graphical trends of total N and total P are given for the individual countries as indices relative to 1990 and data are provided on the total discharge of N and P per capita. Denmark, Sweden and Norway all have positive trends (decreases) for P but negative trends (increases) for N. No clear trends are discernible for Finland.

No state indicator has yet been determined for inland waters for the Nordic countries (Nordic Council of Ministers, 1997). However, as a preliminary indicator, a frequency distribution of total P for all rivers in the different counties (PO_4-P for Iceland) and a general map of nutrient status of lakes and water courses for Nordic countries, is given. As a classification for very nutrient-rich lakes, 50 $\mu g\ l^{-1}$ P is used. In most Nordic countries only a few percent of lakes exceed this level, but over 80% of Danish lakes exceed it.

Two state/impact indicators have been proposed for marine waters for the Nordic countries (Nordic Council of Ministers, 1997). These are: the average winter concentration of phosphorus for selected areas and the distribution of selected weeds. No data have yet been collected for these indicators, and the 1997 report used maps of the nutrient status of Nordic sea water and oxygen levels near the seabed, as preliminary indicators.

Nordic countries (Nordic Council of Ministers 1997) used agricultural land with a winter cover of vegetation (or no tillage in autumn) as a percentage of total agricultural land as a response indicator for inland waters. This is related to changes in agricultural practice aimed at reducing erosion and run-off over winter by changing cultivation practices, applying fertiliser more effectively and improving manure storage. Data were provided for individual countries and as a

Nordic total. Trends were shown as indices relative to 1985, and winter cover had increased from 40% in 1985 to over 65% in 1993 for the Nordic countries overall.

Connection to chemical (includes both chemical and biological-chemical plants) wastewater treatment plants was used as a response indicator for marine waters. Data were provided for percent of population connected to chemical treatment plants for Finland, Norway and Sweden, and trends were indexed against 1975. General figures were given for the different Nordic countries on the percentage of population connected to tertiary treatment (e.g. in 1994 approximately 80% of Danish wastewater was treated by chemical plants, 86% of which had tertiary treatment; in Sweden 90% of population are connected to chemical treatment plants and 9% connected to tertiary treatment plants). Specific reference was made to the necessity of evaluating connection with the need to treat wastewater (e.g. no need for chemical treatment in high natural dispersion areas).

7.3.3 Denmark

In the environmental indicators report, *Miljo indikatorer* (MEM 1996), only marine nutrient inputs were presented graphically as trends in inputs from 1989 to 1994 (tonnes per annum) of nitrogen and phosphorus into the marine environment from rivers, direct emissions and atmospheric deposition.

In the NERI report 'Environment and Society' (NERI 1994), eutrophication was covered by graphic representation of 1991 inputs of phosphorus and nitrogen to watercourses and lakes, and lakes only, from different sources (background, sparsely built-up areas, agriculture, point sources, fish farms, storm water outfalls, treatment plants and atmospheric deposition) (data provided by Kronvag *et al.* 1992, Kristensen *et al.* 1992). Nitrogen input and phosphorus input for 1991 to marine water from different sources were also reported graphically.

No data on nutrient concentrations were presented in the environmental indicators report (MEM 1996); only oxygen concentration in sea water was covered graphically by an indicator presenting, for the Kattegat, trends in oxygen concentration in the period August to October. In the NERI report (NERI 1994), there were several graphic representations of yearly mean concentrations of nitrogen and phosphorus in water courses and coastal waters, trends in winter nitrate concentrations in marine water from 1969 to 1989, trends in phytoplankton production over the period 1950-1990, etc.

Response indicators do not appear to have been used. Instead, results of action plans were given and comparisons of the 'pressures' before and after the implementation of a plan were presented graphically to provide feedback on the effects of policies (NERI 1994).

For example, the measures taken under the Aquatic Environment Plan of 1987, for a reduction in the pressures on the marine areas from nitrogen and phosphorus, have been monitored. This has demonstrated the need to reinforce efforts to reduce nitrate leaching. The immediate objectives are to reduce fertiliser use, and to improve the utilisation of livestock manure with a view to ending the excessive consumption of fertiliser.

Based on the evaluation of the development in livestock manure utilisation, implied in the Action Plan for Sustainable Agricultural Development, a more thorough evaluation has been initiated of the nitrogen consumption of the agricultural sector. On the basis of this evaluation, including the effects of the planned restrictions, the government will consider new initiatives in the sector that could provide an effective incentive for the necessary changes in agricultural practice. The possibility of setting up simplified regulations and using financial tools will be part of these considerations.

7.3.4 Sweden

Sweden does not officially use state indicators. However, in Sweden's OECD performance review (OECD 1996), phosphorus concentrations in lakes and rivers and the percentage which could be regarded as eutrophic or hyper-eutrophic are referred to. This performance review also lists a policy goal of achieving a reduction of 50% in nitrogen leaching by 1995, compared with 1985; a 20% reduction of total commercial fertiliser consumption by 2000, and a reduction in ammonia emissions of 25% by 1995 in South and Southwest Sweden. The policy measures put in place to achieve this are described and their success evaluated. The reduction in fertiliser use is on target, but the reductions in nitrogen leaching and ammonia emissions have not been achieved. The broad goals set do not appear to have assisted in achieving the optimum combination of implementation at a local level.

The trend of reductions in occurrence of algal blooms in coastal waters in recent years is also noted.

7.3.5 Germany

National (Federal) level

The leaflet presenting national, environmental data in terms of indicators (UBA 1995) included the following pressure indicators relevant to eutrophication:

- commercial fertiliser application (kg/ha agricultural land in terms of nutrients N, P, K and $CaCO_3$); data were available for the former West Germany only (1980-1993), the trend was positive (decrease in N, P and total commercial fertiliser application, but inadequate data for the latter in the former East Germany) due to extensification of farming, discontinued cultivation, and more effective fertiliser application;

- Detergent/cleaning agent content (including P) in domestic waste water: presented for 1991-1993, trend positive (decrease) due to a decrease in the use of phosphate containing detergents;

- Nutrient and contaminant input (N and P load) into the Baltic and the North Sea; for the Baltic, organic substances in terms of BOD load were included, and the data were presented as input from rivers, municipalities and industry; for the North Sea, the data were presented in terms of input from rivers, sewage sludge and industrial waste (in both cases, 1990 data only, hence no comment on trends);

- Volume of domestic waste water, total (data for 1991 only) and connected to sewage treatment (1975-1991) (the latter could be considered a response indicator, but used here in conjunction with a pressure indicator); there appeared to be no trend in the latter in the former West Germany (former East Germany: data for 1991 only).

The indicator summary leaflet on environmental data (UBA 1995) included water quality data (state indicators), as follows:

NH_4-N, NO_3-N and total P concentrations in the rivers Rhine and Elbe (1980-1992); trends were positive (decreasing) for NH_4-N and P concentrations, but negative (increasing) for NO_3-N concentrations considered due to diffuse input from agriculture.

Total P and total inorganic N concentrations, and phytoplankton biomass were presented in the lakes Bodensee-Obersee (1991-1993); the trends were as follows: P concentrations fell due to increased P removal in sewage treatment plants in the catchment and the introduction of low phosphate detergents; the phytoplankton biomass remained high, consequently further P reductions (response) were considered essential; N concentrations increased (mainly NO_3) due to diffuse input from agriculture.

A related indicator, nitrate concentrations in drinking water was also presented (1915-1989); the trend was negative (increasing) due to agriculture.

The environmental data leaflet (UBA 1995) used the response indicator, percentage of population connected to waste water treatment plants, broken down into mechanical treatment only, and biological/other (tertiary) treatment. The trend for connection to biological/tertiary treatment facilities was positive over the period 1975 to 1991 in the former West Germany (data inadequate for former East Germany).

Research projects to develop indicators for national use

In the project to develop indicators for national use (Walz *et al.*, 1997), Germany proposed similar indicators to those used by the Nordic countries to measure N and P surpluses (N and P use as commercial fertiliser and manure; expressed as t/km^2 used on agricultural land) and, in the medium term, an additional indicator for the nutrient balance on agricultural land. In addition to this, Germany proposed indicators for inputs to its watercourses as N and P (in t/a), as well as amounts of N and P exported to marine waters and other countries via international rivers (t/a; Rhine, Weser, Elbe, Ems, Danube). The proposed German system also identified linkages to other pressure indicators, i.e. emissions of NO_2 and NH_3, atmospheric depositions of N compounds and soil erosion.

The state indicators proposed for national use in this study (Walz *et al.* 1997) were as follows:

- actual load/critical load balance of nitrogen deposition in forest areas;
- water quality distribution: concentrations of N and P; and
- P-concentrations near Helgoland (North Sea) and (medium term) in the Baltic Sea.

The links to groundwater contamination with NO_3 were also pointed out.

Walz *et al.* (1997) proposed the following response indicator, 'percentage of the population connected to biological sewage treatment plants with elimination of N and P' (i.e. tertiary treatment). For long term use, the indicator, 'measures for the reduction of fertiliser use', was suggested.

In addition, the link with the following indicators was mentioned:

- Percentage area of groundwater reserves,
- Measures for implementation of an extensive agriculture;
- Capacity/percentage of NO_x/SO_2 abatement equipment at point sources; and
- Investments in environmental protection.

The approach of the Wuppertal Institute (Loske and Bleischwitz, 1996), proposing a small number of highly aggregated indicators, included pressure indicators only; 'synthetic fertilisers' under the category 'selected compound emissions' and a eutrophication index (one of only five pressure indices, see Table 5.3) though the approach does not appear to have been applied in practice to date.

Regional (Federal State) and local/district level

The selection of indicators for presentation of the report on environmental data in the Federal State of Baden-Württemberg did not include any indicators directly related to eutrophication which was not seen as a key environmental theme for the State (LfU 1997). The local/district study did not use any eutrophication indicators either (Diefenbacher *et al.*, 1997). However, the project aimed at the development and presentation of indicators for sustainable development in Baden-Württemberg (Pfister *et al.*, 1997) included the pressure indicator 'N-compound deposition' (actual in kg/ha/a, and per man-made capital per capita) under the category 'eutrophication/nitrate in groundwater' (there are no marine waters in Baden-Württemberg). The data were presented on an annual basis for the period 1988 to 1994, together with the state indicator 'groundwater contamination with NO_3' (data for 1992-1995 only); the overall trend was negative (strong increase since 1992), i.e. concluded to be unsustainable ('red light' signal, indicating the need for a response).

In addition, Pfister *et al.* (1997) used the pressure indicator, BOD load in effluents of sewage treatment works (1980-1993) in combination with the state indicator, BOD in the river Neckar; the trend was positive (decreasing BOD), hence the conclusion a 'green light', no action needed in this respect.

The report on environmental data for Baden-Württemberg (LfU 1997) included the state indicator, nitrate concentrations in groundwater, and concluded that the trend was stagnant. In addition, this report used the biological/ecological condition of rivers (proportion in classes I to II - unpolluted to moderately polluted) (data 1974-1991); this trend was found to be positive.

The FEST local/regional study (Diefenbacher *et al.*, 1997) included an indicator 'Percentage of water abstracted with NO_3 concentration <25 mg l^{-1}'. The trend seemed to be positive on a district basis (Rhine-Neckar) and stagnant locally (town of Heidelberg). However, the explanatory text relating the trends to sustainability, stressed the difficulties of interpretation of this indicator, i.e. nitrate concentrations may be decreasing/remaining constant because of the use of alternative, deeper groundwater resources rather than because of improvements in the quality of groundwaters; this would be an unsustainable practice.

Pfister *et al.* (1997), in the presentation of indicators for sustainable development in Baden-Württemberg, used nitrate concentrations in groundwater (1992-1995 data), and total P concentration in lake water (Bodensee, data from 1970 to 1993), in terms of actual, and per man-made capital per capita; whilst the trend for nitrate concentration in groundwater was negative (increase, 'red light', indicating the need for a response), the trends for P in lake water were positive (decreasing since about 1980) and the conclusion was a 'green light', i.e. no need for action.

This is in contrast to the UBA (1995) report (see above) which included another indicator (impact), 'phytoplankton biomass' resulting in the conclusion that further reductions in P input were necessary.

In addition, Pfister *et al.* (1997) have used BOD in the river Neckar (1975-1995) in combination with the pressure indicator, BOD in effluents of sewage treatment works; the trend was positive (decreasing BOD), hence the conclusion a 'green light', no action needed.

The above presentations of environmental data at regional, local and district level did not include any response indicators relating to eutrophication.

7.4 Discussion

7.4.1 Global Warming

At a national level, pressure and response indicators are likely to be most relevant, since state indicators, such as atmospheric concentrations of greenhouse gases and temperature, are likely to be presented at European or global level.

Denmark and Germany have used the largest number of indicators on this issue, and including indicators for all categories (pressure, state and response).

The most common **Pressure** indicator for global warming is CO_2 emission, often presented as CO_2 emission per capita, by source, or for the Nordic states per unit of GDP. Other common indicators include: index of total greenhouse gases (used in the UK and Germany but not by the Nordic Council or Sweden), N_2O emissions and CH_4 emissions. In Germany, figures are also presented at the regional level and local/district level but the indicators used vary considerably so that it would be difficult to build a national picture from the local level.

Areas requiring further development, may be as follows:

(a) an indicator for methane emissions; and

(b) indicators providing information on the main sources of emissions of greenhouse gases in total (i.e. sectoral disaggregation).

Numerous **State** indicators have been developed. These are generally related to air temperature and to individual concentrations of CO_2 and other greenhouse gases. Germany proposed the use of the global greenhouse gas 'radiative force index' (used as an indicator of sustainable development in the UK), but it does not seem to have been applied in practice so far.

Several countries, but not the UK, reported related **Impact** indicators, for example, number of extreme weather condition events as in the Nordic states, duration of ice cover in Finland, and changes in migration or breeding success of birds as in Denmark.

Few true **Response** indicators have been developed, although most countries appear to use progress against goals for Pressure reduction, for example progress towards CO_2 emission reductions, as a response indicator. These are generally used at the national or at a policy-related level. Examples of response indicators are:

- energy efficiency (medium to long term) or energy intensity (short term) proposed by the OECD and used by Germany in its summary environmental data report;
- fossil fuel consumption as a percentage of total energy consumption, used by the Nordic countries;
- financial support for renewable energy use, energy use for domestic heating per m^2, average efficiency of electric power production, average usage of passenger vehicles, all proposed for use in Germany.

Differences in indicator expression and definition make comparisons difficult; for example indicators may be expressed in a variety of ways (per capita, per GDP etc.) and may omit important contributions from specific sectors, such as the omission of energy consumption in transport in the Nordic States.

7.4.2 Eutrophication

Relatively few countries identify eutrophication as a separate issue and it is often considered a measure of impact, indicative of changes in status of water quality, rather than an environmental issue in itself. It therefore appears unlikely that the EEA will consider this as a separate issue; it is more likely to consider it under a general heading of water quality.

With the exception of Germany, there is less use of indicators for eutrophication than for global warming, and less consistency in indicator selection.

The OECD proposed ten indicators for eutrophication, four pressure indicators, two state indicators and four response indicators with varying time scales of application.

Pressure indicators commonly used, which may be appropriate for use in the UK, are:

- surplus agricultural inputs of nitrogen and phosphorus (tonnes and tonnes/ha) as used by the Nordic states for inland waters and proposed for use in Germany;

- total discharges of nitrogen and phosphorus to marine waters as used by the Nordic states and for all waters as used in Denmark;

- longer term indicator of nutrient balance as proposed by the OECD and selected by Germany;

- atmospheric emissions of nitrous oxides and NH_3, as proposed by Germany.

The Wuppertal Institute in Germany proposed the use of a small number of highly aggregated indicators, 'synthetic fertilisers' and a 'eutrophication index', but this does not appear to have been applied in practice as yet.

As with global warming, several countries report on progress towards pressure targets as response indicators. A number of true **Response** indicators have been developed reflecting the nutrient reduction policies in place. Examples are:

- connection to various levels of waste water treatment plants as in the Nordic countries and proposed for use in Germany;

- agricultural land with winter cover as in the Nordic countries;

- measures for the reduction of fertiliser use (Nordic, and proposed in Germany).

The linkages between different P-S-R indicators currently appear to be poorly defined because there is still debate about the most appropriate indicators, and many of those currently in use appear to be used simply because of data availability. For example, for the Nordic countries, Table 7.3 illustrates that the indicators for freshwaters concentrate on linkages between agricultural inputs of P but have no measures of P contributions from sewage; whilst for marine waters, where nitrogen is generally considered most important, P still features as a state indicator. The response indicator is also more relevant to P removal than N removal (it does not provide a measure of advanced biological treatment, necessary for N removal), and is a point source indicator, despite the fact that nitrogen inputs to the sea from arable areas in southern Scandinavia are twice that of all point sources combined.

Table 7.3 Summary of P-S-(I)-R indicators used for eutrophication of inland waters and marine waters

	Pressure	State/Impact	Response
Inland Waters	Surplus N and P from fertiliser & manure	P concentrations (preliminary indicator)	Winter green agricultural land cover
Marine Waters	Total discharges N and P	- Distribution of selected weeds - Average winter concentration of P	Connection to chemical wastewater treatment plants

NERI has undertaken a pilot study of integrated environmental assessment (IEA) on eutrophication for the EEA (NERI 1997). The IEA looks at natural and human processes which determine current and future environmental state and was conducted on a European scale using the D-P-S-I-R framework. An important aspect of this work was concerned with identifying causal links between driving forces and pressures. Therefore, whilst it does not suggest appropriate indicators, it does review 'processes' which are important and identifies data gaps; overall, this may help in the identification of appropriate indictors. The study concluded that, currently, no institutional mechanism or network addresses the full framework of the D-P-S-I-R causal chain for eutrophication, although this was partly covered by HELCOM, OSPARCOM and the EEA/ETC network. It recommended expansion of the EEA network to address this.

8. CONCLUSIONS

There is a need to simplify the presentation of environmental data in an accessible but representative form to inform the public, provide a basis for policy decisions and to assess the impact of policies. However, there seems to be a conflict of interests between simplification (politicians/public) and true representation of the situation (scientists/economists).

Indicator systems

Environmental indicators are being developed and used at international level and in the countries studied. Due to the current general interest in sustainable development, indicator systems often focus on this aspect and there is considerable overlap between purely environmental, and sustainability indicator systems. The latter focus on resources and comprise environmental, as well as socio-economic, and sometimes institutional indicators.

Most indicator systems are largely based on the OECD **P-S-R** model, i.e. sets of indicators, grouped into environmental themes or issues, to describe **Pressures** (negative impacts) on the environment, the **State** of the environment, and societal **Responses** designed to improve the state of the environment (positive impacts).

Some have developed the model further, for example the US-EPA, by adding an **Effects** category to describe the relationship between Pressures, State and Responses. The European Environment Agency has refined the model to include **Driving forces** (human activities affecting the environment) and **Impact** (to describe ecological or other effects of a given state of the environment) (**D-P-S-I-R**). The latter model has been represented as a cycle to stress the need to consider the entire system with Responses ultimately affecting Driving forces (or Pressures or Status directly).

An interesting feature of the proposed German indicator system, which is closely based on the OECD model, is the specification of links to indicators in other themes. This method is useful in that it stresses the relationships between separately defined themes and indicators.

Indicators are also used to assess performance against targets or national goals (**Performance Indicators**). The approach in Sweden focuses on this aspect by selecting indicators closely linked to national targets, establishing environmental quality (baseline) criteria against which to measure indicators as ratios.

A further simplification of data can be achieved through the formulation of **Indices** (aggregated or weighted parameters or indicators); these are being developed, particularly as sustainability indicators.

Criteria for indicator selection

The main criteria for selecting indicators are policy relevance and utility, analytical soundness, and measurability (OECD). Other factors which have been stressed, are biological relevance, early warning, and wide geographical applicability (EEA).

In Germany, key criteria were identified as ecological soundness, quantifiability and data availability and appropriateness for end-users; much emphasis was placed on correctly defining the relationships between potential indicators by preparing detailed background documents for each environmental theme prior to indicator selection.

An important concept, 'response elasticity', has been added by EUROSTAT; this relates to the ease with which responses (actions) may be implemented in practice. This could help in prioritising actions, but should not be used as a means to omit or delay actions which may be urgently needed, but are difficult to implement.

Indicator selection has been mainly carried out by the scientific community, although economists have also taken an active part, and some wider participation has been encouraged, mainly in sustainability indicator selection.

In practice, the main driving force for indicator selection appears to have been data availability, understandably, because of the need to implement indicator application as early as possible. However, this may detract from defining real needs and to guide and focus future data gathering needs.

Indicators selected and used

Indicators seem to be used primarily for presenting the state of the environment (sometimes including trends) though pressure indicators (e.g. emissions) are often included, whilst response indicators are rarely presented. Consequently, the closed cycle which is probably the most important aspect of an indicator system, is often neglected.

Moreover, the use of indicators as such is limited, and it is often difficult to distinguish between actual use of indicators (as part of an indicator system) and simply presentation of environmental data in a way which is similar to indicator presentation.

A closer study of indicator use for global warming and eutrophication has shown that completely unrelated indicators are often used within one issue; this means that it is not possible to assess the impact of pressures or responses on the state of the environment. Moreover, the study has shown that a wide variety of indicators are used: even where the indicators appear to be similar, they are expressed in different ways, and may include or exclude certain contributions (sectors); consequently no meaningful comparisons can be made.

In view of the limited application of actual indicators to-date, it is not possible to assess the extent and means by which policy decisions are based on indicator presentations, nor whether any systems in use have proved useful so far. However, there seems to be a need for further simplification.

Some interesting methods of presenting the assessment of indicators in terms of trends, include smiling/neutral/unhappy faces and traffic signals (red/- warning of negative trend, amber/= stagnant, but keep monitoring, green/+ ok, positive trend).

9. RECOMMENDATIONS

Although most approaches are broadly based on the OECD model, many different systems seem to be emerging at international, national, and regional/local level. There is a need to co-ordinate efforts to allow meaningful comparisons between regions and countries, and assessments at international and global level.

As with indicator systems as a whole, a wide variety of indicators are being developed and used in a variety of ways; there is a clear need to standardise indicators, not only in terms of the specific indicators used, but also in the way these are expressed and what is to be included (i.e. all major sources of a particular pressure).

It is particularly important to establish clearly the relationships between indicators of different categories (e.g. P, S and R) and relationships between different environmental themes or issues, and to use full sets of indicators. Only this approach can demonstrate the effects of pressures and responses on the state of the environment.

In indicator selection, more emphasis needs to be placed on needs for indicators, rather than data availability, followed by defining future data requirements on this basis. If indicators are selected on a sound scientific basis, this should lead to more focused environmental monitoring and, thus, could save costs in the long term.

The search for further simplification of indicator systems, for example for dissemination of easily accessible information to the public, is continuing. With this approach there is a risk of over-simplification which may no longer reflect the true situation. Nevertheless, there is clearly a need for this, and it can be valuable, if the simplified system is based on a thorough scientific evaluation of potential indicators, leading to the formulation of a small number of indices. At the same time, a more complex system of well connected indicators (from each category of the P-S-R or D-P-S-I-R cycle) should be used to examine progress on specific topics in more detail.

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APPENDIX A - INDICATORS SELECTED

Table A1. Summary of OECD Indicators by Environmental Issue (OECD 1994)

	Pressure		State		Response	
Issues	**Indicators of environmental pressures**		**Indicators of environmental conditions**		**Indicators of societal responses**	
Climate change	• Index of greenhouse gas emissions** • *CO_2 emissions*	M S	• *Atmospheric concentrations of greenhouse gases*** • Global mean temperature**	S S	• Energy efficiency** • *Energy intensity* • Economic and fiscal instruments	M/L S M
Ozone layer depletion	• Index of apparent consumption of ozone depleting substances** • *Apparent consumption of CFCs and halons*	M S/M	• *Atmospheric concentrations of ozone depleting substances*** • Ground level UV-B radiation**	S/M M	• CFC recovery rate**	M
Eutrophication	• Emissions of N and P in water and soil (--> nutrient balance)** • *N from fertiliser use and from livestock* • P from fertiliser use and from livestock	L S S	• *BOD/DO, concentration of N and P in inland waters** and in marine waters***	S/M M/L	• % of population connected to biological and/or chemical sewage treatment plants** • *% of population connected to sewage treatment plants* • User charges for waste water treatment • Market share of phosphate-free detergents	M/L S M S/M
Acidification	• Index of acidifying substances** • *Emissions of NOx and SOx*	M/L S	• Exceedence of critical loads of pH in water and soil** • *Concentrations in acid precipitation*	M/L S	• % of car fleet equipped with catalytic converters** • Capacity of SOx and NOx abatement equipment of stationary sources**	S/M M/L

Table A1. cont.

	Pressure		**State**		**Response**	
Issues	**Indicators of environmental pressures**		**Indicators of environmental conditions**		**Indicators of societal responses**	
Toxic contamination	• Emissions of heavy metals** • Emissions of organic compounds** • *Consumption of pesticides*	M/L L S/M	• Concentration of heavy metals and organic compounds in env. media and in living species** • *Concentration of heavy metals in rivers*	L S/M	• Changes of toxic contents in products production and processes** • *Market share of unleaded petrol*	L S
Urban environmental quality	• Urban air emissions: SOx, NOx, VOC** • *Traffic density* - urban - *national* • Degree of urbanisation	M/L M S S/M	• Population exposure to: - air pollution** - noise** • Ambient water conditions in urban areas**	L M M/L	• Green space** • Economic, fiscal and regulatory instruments** • Water treatment and noise abatement expenditures	M/L M S/M
Biodiversity/ landscape	• Habitat alteration and land conversion from natural state**	L	• *Threatened or extinct species as a share of total species known***	S	• *Protected area as % of national territory*** and by type of ecosystem**	S L
Waste	• *Waste generation*** - *municipal* - *industrial* - *nuclear* - *hazardous*	S S S S/M	*Not applicable*		• Waste minimisation • Recycling rate • Economic and fiscal instruments, expenditures	L S/M M
Water resources	• *Intensity of use of water resources***	S	• Frequency, duration and extent of water shortages**	M/L	• Water prices and user charges for sewage treatment**	M
Forest resources	• *Actual harvest/ productive capacity*	M	• Area, volume and structure of forests**	S/M	• Forest area management and protection**	M/L
Fish resources	• *Fish catches***	S	• Size of spawning stocks**	M	• Regulation of stocks (quotas)	M
Soil degradation (desertification & erosion)	• Erosion risks: potential and actual land use for agriculture** • *Change in land use*	L S	• Degree of top soil losses**	M/L	• Rehabilitated areas**	M/L

Table A1. cont.

	Pressure		State		Response	
Issues	**Indicators of environmental pressures**		**Indicators of environmental conditions**		**Indicators of societal responses**	
General indicators, not attributable to specific issues	• *Population growth & density***	S	Not applicable		• Environmental expenditures**	M/L
	• *Growth of GDP***	S			• *Pollution control and abatement expenditures*	S/M
	• *Private final consumption expenditure***	S			• Public opinion**	S
	• *Industrial production***	S				
	• *Structure of energy supply***	S				
	• *Road traffic volumes***	S				
	• *Stock of road vehicles***	S				
	• *Agricultural production***	S				

a) This table summarises the indicators of the core set proposed by the OECD Group on the State of the Environment. It presents "main" indicators (pointed out by a double asterisk **), complementary indicators to accompany the message conveyed by "main" indicators, and proxy indicators when the "main" indicator is currently not measurable. The indicators for which data were presented in the publication (OECD 1994) are printed in italics. Each indicator is followed by a character specifying its availability, as follows:

S = short term, basic data currently available for a majority of OECD countries;

M = medium term, basic data partially available, but calling for a supplementary effort to improve their quality (consistency, comparability) and their geographical coverage (number of countries covered);

L = long term, basic data not available for a majority of OECD countries, calling for a sustained data collection and conceptual efforts.

Table A2. Indicators selected by UN-CSD for environmental category (UN-CSD 1996)

Agenda 21 chapters	Driving force indicators	State indicators	Response indicators
Protection of the quality and supply of freshwater resources	• annual withdrawals of ground and surface water • domestic water consumption per capita	• groundwater reserves • concentration of faecal coliforms in freshwater • biochemical oxygen demand in water bodies	• wastewater treatment coverage • density of hydrological networks
Protection of the oceans, all kinds of seas and coastal areas	• population growth in coastal areas • discharges of oil into coastal waters • releases of nitrogen and phosphorus effluent to coastal waters	• maximum sustained yield for fisheries • algae index	
Integrated approach to land resource planning and management	• land use changes	• changes in land condition	• decentralised natural resource management at local level
Managing fragile ecosystems: combating desertification and drought	• population living below poverty line in dry land areas	• national monthly rainfall index • satellite derived vegetation index • land affected by desertification	
Managing fragile ecosystems: suitable development in mountain areas	• population change in mountains areas	• sustainable use of natural resources in mountain areas • welfare of mountain populations	
Promoting sustainable agriculture and rural development	• use of agricultural pesticides • use of fertilisers • irrigation percent of arable land • energy use in agriculture	• arable land per capita • area affected by salinisation and water logging	• agricultural education

Table A2 cont.

Agenda 21 chapters	Driving force indicators	State indicators	Response indicators
Combating deforestation	• wood harvesting intensity	• changes in forest area	• managed forest area ratio • protected forest area as a percent of total forest area
Conservation of biodiversity		• threatened species as a percent of total native species	• protected area as a percent of total area
Environmentally sound biotechnology management			• R&D expenditure on biotechnology • existence of national biosafety regulations or guidelines
Protection of the atmosphere	• greenhouse gas emissions • sulphur oxide emissions • nitrogen oxide emissions • consumption of ozone depleting substances	• ambient concentrations of pollutants in urban areas	• expenditure on air pollution abatement
Environmentally sound management of solid waste and sewage-related issues	• generation of industrial and municipal solid waste • household waste disposed per capita		• expenditure on waste management • waste recycling and reuse • municipal waste disposal
Environmentally sound management of toxic chemicals		• chemically induced acute poisonings	• number of chemicals banned severely restricted
Environmentally sound management of hazardous waste	• generation of hazardous waste • imports and exports of hazardous waste	• area of land contaminated by hazardous waste	• expenditure on hazardous waste treatment
Safe and environmentally sound management of radioactive waste	• generation of radioactive waste		

Table A3. SCOPE indicators (SCOPE 1994)

Source function Net diminution of natural resources	• reduction of arable soils and soil quality • reduction of wood stock and quality of forest • reduction of fish stock and fish quality • reduction of groundwater resources and quality of water • *(reduction of mineral stock)* • *(reduction of hydrocarbon)*
Gap function Pollution	• emission of gases damaging ozone layer (CFC, halons) • emission of greenhouse gases (CO_2, CH_4, CFC, N_2O, halons) • emission of acid gases (SO_2, NO_x) • emission of eutrophying substances (N and P) • emission of toxic substances (pesticides, radioactive substances, priority substances) • solid waste landfilled
Biological function Risk for ecosystems	• geographic distribution of population • geographic distribution of livestock • geographic distribution of infrastructures • geographic distribution of industrial activities • geographic distribution of change in land occupation • geographic distribution of imported species • geographic distribution of ecosystems per type of ecosystem • geographic distribution of protected areas
Quality of life function Impact on human wealth	• exposure to bad quality drinking water • exposure to polluted atmosphere • exposure to environmental diseases • exposure to contaminated food • work exposure to toxic • *(exposure to noise)*

(other potential indicators)

Table A4. Selected indicators proposed for the German national indicator system (Walz *et al.* 1996)

Pressure	State	Response
Global Warming		
• CO_2-index of greenhouse gas emissions [GWP 100a] Emissions/use of • CO_2, CH_4, N_2O, CFCs 11/-12/ -13/-113/-114/-115, CCl_4, methyl chloroform • *CFC-substitutes, other greenhouse gases (medium/ long term*	• Atmospheric concentrations of CO_2, CH_4, N_2O • Global mean temperature • *Global radiative forcing (long term)*	• Degree of fulfilment of the CO_2 reduction target • *Financial support of renewable energies and rational energy use (medium term)* • Energy use of private heating (per m^2) • Average efficiency of electric power production • Average energy use of passenger cars
Links to indicators in other issues		
• Energy use		• Decrease in production of ozone depleting substances (CFC-11-index) • Measures for the reduction of fertiliser usage
Ozone Layer Depletion		
• Use of ODP (CFC 11-index) (all substances of the CFC-Halon-interdiction regulation; *medium term: other HCFC)* • Use in t/a CFC	• Local constitution of the ozone layer • *Ground level UV-B-radiation (medium term)*	• Decrease in production of ODPs (CFC-11-index) (all substances of the CFC-Halon-interdiction regulation; *medium term: other HCFC)*
Eutrophication		
• N and P fertiliser use (industrial fertiliser + manure; t/km^2 used land); medium term nutrient balance on agricultural area) • N- and P- input in national water flows (t/a) • N- and P-freight to oceans/ foreign countries (t/a; Rhine, Weser, Elbe, Ems, Donau)	• Actual Load/Critical Load balance of nitrogen deposition in forest areas • Water quality distribution: concentrations of N and P • N- and P-concentrations near Helgo-land and *(medium term) in the Baltic Sea*	• % of the population connected to biological sewage treatment plants with elimination of N and P • *Measures for the reduction of fertiliser use (long term)*
Links to indicators in other issues		
• Emissions of NO_x and NH_3 • Atmospheric depositions of N compounds • Soil erosion	• Groundwater contamination with NO_3^-	• % area of groundwater reserves • Measures for implementation of an extensive agriculture • Capacity/% of NO_x/SO_2 abatement equipment at stationary sources • Investments in environmental protection

Table A4. continued

Pressure	State	Response
Acidification		
• Emissions of acidifying substances (acidification index) • Emissions of SO_2, NO_x, NH_3 • International transport balance of S and N	• SO_2- and NO_x-concentrations in the atmosphere • Deposition of S- and N-compounds *(medium term incl. wet N-deposition and dry NH_3-deposition)* • Distribution of actual/critical load balance for acidification of forest soils	• Capacity/% of NO_x/SO_2 abatement equipment at stationary sources • % of car fleet equipped with catalytic converters • Regulations for maximum sulphur content in mineral oil products • Reduction targets for N and S from UN-ECE N and S protocols
Links to indicators in other issues		
• N-fertiliser use • Car traffic intensity (km/km^2)	• Forest damage area	• Measures for implementation of an extensive agriculture • GREENHOUSE EFFECT • Investments in environmental protection
Toxic contamination		
• **Total soil index** • Soil index heavy metals • Soil index pesticides	• **Total atmospheric index** • Atmosphere index main particles • Atmosphere index heavy particles • Atmosphere index polycyclic aromatic hydrocarbons (PAH) • Atmosphere index NMVOC • **Total water index** • Water index heavy metals • Water index pesticides, NMVOC and ubiquitous compounds	
Links to indicators in other issues		
• WASTE • Emissions VOC, TSS in urban control areas • Sewage treatment output • Intensive crop agriculture (in ha)	• Concentration of pesticides in groundwater/drinking water • Concentration VOC, TSS	• Extensive agriculture • Capacity/% of NO_x/SO_2 abatement equipment at stationary sources • % of car fleet equipped with catalytic converters

Table A4. continued

Pressure	State	Response
Urban environmental quality		
• Emissions von SO_2, NO_x, particles and VOC in urban control areas • *Distribution of traffic density in counties/cities*	• Concentration of SO_2, NO_x, particles and VOC from the Länder measurements • Concentration of O_3 from the Länder measurements • *Number of winter smog episodes (medium/long term)* • *Benzene concentrations (long term)* • % of population with noise nuisance	• % public traffic of private traffic, non-motorised traffic • *Investment in traffic infrastructure: % individual, local public and railway traffic (medium term)* • Noise limits for motor vehicles
Links to indicators in other issues		
• TOXIC CONTAMINATION • Energy use	• Soil sealed in % of area • TOXIC CONTAMINATION • WATER RESOURCES	• Capacity of NO_X/SO_2 abatement equipment at stationary sources • % of car fleet equipped with catalytic converters • Regulations for maximum sulphur content in mineral oil products
Biodiversity/landscape		
• Intensive crop agriculture (in ha)	• % endangered/extinct species (fauna and flora)	• Measures for implementation of an extensive agriculture
• % traffic area and urban area	• % endangered/extinct biotopes	• Protected areas as % of national territory (national nature reserves and national parks)
• Isolation effects of landscape: decrease in coherent areas with low traffic	• *Index of ecosystem change (e.g. leading bird species) (medium term)*	
Links to indicators in other issues		
• N- and P-fertiliser use • Emissions of SO_2, NH_3, NO_x • Structure of waterways • Land use • Fish catch		• Uncultivated agricultural land • EUTROPHICATION • ACIDIFICATION • Restoration of waterways

Table A4. continued

Pressure	State	Response
Waste Waste generation: • Total amount • private waste + similar commercial waste (total/per head) • industrial waste • rumble, excavated soil • Hazardous waste • Radioactive waste	• Treatment of waste (dumpling, combustion, compost, others); Export • Static operation time of waste deposits • *Stock of disposed municipal and hazardous waste (long term)* • Stock of radioactive waste	• Recycling rates glass, paper, aluminium • *% separately treated biowaste (medium term)* • Rate of eutilisation of industrial waste • *Yield and level of hazardous waste levies (long term)* • *Financial support of waste prevention measures (long term)*
Links to indicators in other issues • Non-energetic use of resources	• sewage sludge, agricultural waste (liquid manure)	• Investment in environmental protection
Water resources and water quality • Intensity of use of water resources (balance of water use and natural water supply) • Water use municipal and industrial • Individual water use (households) • Water output from municipal and industrial sewage treatment plants • *Water way construction (long term)*	• Groundwater: ratio withdrawal to production • Nitrate concentrations in drinking water (short term) and *groundwater (medium term)* • *Pesticide load in groundwater/ drinking water (medium term)* • % clean water of total extracted drinking water • Biological index of the constitution of surface water • Chemical index of the constitution of surface water *(medium term)* • *Structure of water bodies: morphology incl. border (long term)*	• Process intensity of water use (ratio of used water to consumed water in industry) • Drinking water prices and sewage levies • % national territory with water reserves • Total amount of sewage water levies • *Restored water bodies (long term)*
Links to indicators in other issues • Toxic index pesticides • N and P fertiliser use • Intensive crop agriculture	• TOXIC CONTAMINATION	• EUTROPHICATION • Investment in environmental protection

Table A4. continued

Pressure	State	Response
Forests		
• Ratio actual harvest/productive capacity	• Forest area in km^2 • Forest damage • Endangered forest biotopes • Forest structure (share of coniferous, deciduous, mixed forest)	• % forest protection area of total forest area • Forest management ("Helsinki" - indicator) (long term)
Links to indicators in other issues		
• Emissions of SO_2, NO_x and NH_3 • N fertiliser use • Emissions of VOC	• Actual load/critical load forest soils • Toxic index atmosphere: NMVOC	• ACIDIFICATION • EUTROPHICATION
Fish resources		
• TOXIC CONTAMINATION (water) • Emissions of SO_2, NO_x and NH_3 • N and P fertiliser use • Water output from municipal and industrial sewage treatment plants	• TOXIC CONTAMINATION (water) • N and P concentrations North Sea and Baltic Sea • Structure of water bodies • Biological index surface water • Chemical index surface water	• EUTROPHICATION • ACIDIFICATION • Restoration of water bodies • Yield of sewage levies
Soil resources		
• % crop land of national territory • % of sealed soil	• Soil erosion, erosion risk • *Soil compression (long term)*	• % uncultivated agricultural land of total agricultural land
Links to indicators in other issues		
• Emissions SO_2, NO_x and NH_3 • N and P fertiliser use • Intensive agriculture • TOXIC CONTAMINATION	• Actual load/critical load acid deposition on forest soils • Actual load/critical load nitrogen deposition on forest soils • TOXIC CONTAMINATION	• Extensive crop agriculture • Measures for implementation of an extensive agriculture • ACIDIFICATION • EUTROPHICATION

Table A4. continued

Pressure	State	Response
Radiation a) Main indicator:		
	• Average effective equivalent dose of antropogenically caused radiation	
b) Nuclear facilities, nuclear tests and accidents:		
• Total β radiation in atmosphere (Becquerel/m^3) • Total γ dose (μGy/h) • Gamma spectrometry in food (Bq/kg)	• Average effective equivalent dose of regular operation of nuclear facilities, nuclear tests and accidents (mSv/a)	• Limit total body dose for the population (mSv/a) • Limiting value for food content of Cs-134 and Cs-137 (Bq/kg)
c) Radon radiation:		
• Radon radiation in houses (Becquerel/m^3)	• Average effective equivalent dose of radon (mSv/a)	• Recommended radon level for houses (Bq/m^3)
d) Risk indicators:		
• Number of national nuclear reactors in operation	• Number of recorded events in nuclear reactors (International Nuclear Event Scale INES)	
e) Comparing indicators:		
• Number of medical examinations with nuclear sources (% of the population)	• Average effective equivalent dose of medical examinations (mSv/a)	
	• Average effective dose of natural radiation (mSv/a)	
Links to indicators in other issues • Generation of radioactive waste	• Stock of radioactive waste	
General indicators • Population growth/density • BIP (incl. share of industry, agriculture) • Private consumption • Energy use • Car traffic in km/a • Car stock in mill • Modal split • Land use • Non-energetic resource use (biotic/abiotic)		• Expenses for environmental protection • Investment in environmental protection • Environmental consciousness • *Jobs in the environmental sector (medium term)* • *Share of environmental levies of total levies (medium term)*

Indicators considered to be feasible only in the medium to long term are shown in italics

APPENDIX B EXAMPLE OF SUSTAINABILITY INDICATOR PRESENTATION IN GERMANY

1. **Issue 2: Climate - CO_2 concentration (A and B) - CO_2 emission**

   (A/C actual, B/D expressed in terms of man-made capital per capita)

   Overall assessment: negative (unsustainable) trend (red light)

1. **Issue 4: Eutrophication - Phosphorus concentrations in Lake Constance ***

   (A. actual, B expressed in terms of man-made capital per capita)

   Overall assessment: positive (sustainable) trend (green light)

2. **Issue 11: Land Use - Percentage covered/built up surface area**

   (A. actual, B expressed in terms of man-made capital per capita)

   Overall assessment: stagnant trend (amber light)

Source: Pfister *et al.*, 1997

* error in heading of original heading

2. Klimastabilität

Eine Klimaerwärmung gefährdet die Stabilität der Ökosysteme. Als Zustandsmeßgröße wird hierfür das Treibhausgas Kohlendioxid (CO_2) gewählt. Die **Abbildung A** zeigt einen stetigen Anstieg der atmosphärischen CO_2-Konzentration und damit eine nicht-nachhaltige Entwicklung. Das Verhältnis von CO_2-Konzentration und Nettoanlagevermögen pro Kopf (NAV / Kopf) ergibt hingegen einen fallenden Verlauf **(Abbildung B)**. Der Anstieg der CO_2-Konzentration kann also möglicherweise durch erhöhtes künstliches Kapital ausgeglichen worden sein.

Als Belastungsmeßgröße dienen hier die CO_2-Emissionen. Im Zeitverlauf insgesamt betrachtet liegen diese – konjunkturabhängig stark schwankenden – Emissionen seit 1986 auf einem höheren Niveau als zuvor **(Abbildung C)**. Die Verhältnisgröße zwischen den CO_2-Emissionen und dem künstlichen Kapital zeigt bis etwa zum Jahr 1982 einen fallenden Verlauf. Danach verbleiben die Werte auf etwa demselben Niveau. Auch hier wird durch eine seit 1982 nahezu konstante Ressourcenintensität eine nicht-nachhaltige Entwicklung angezeigt **(Abbildung D)**.

Die Ampel ist deshalb auf „Rot" geschaltet.

Abbildung A

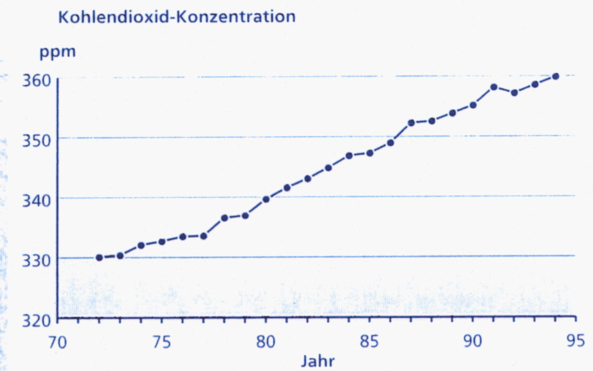


Abbildung B

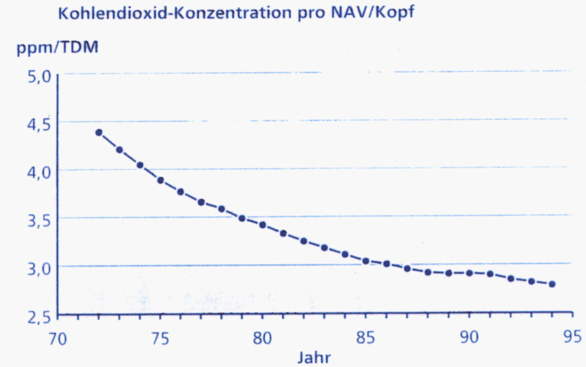


Abbildung C

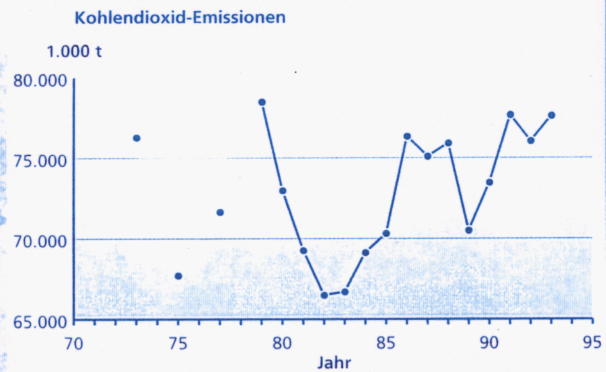
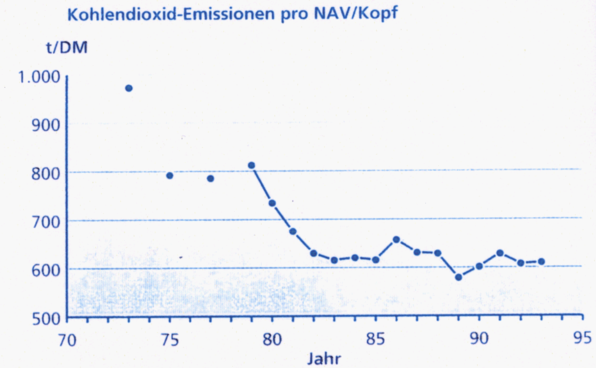
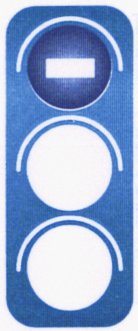
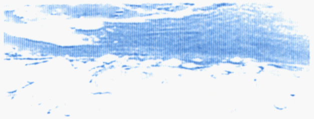


Abbildung D







Anders ist die Situation für stehende Gewässer wie den Bodensee zu beurteilen. Dort kann als Zustandsmeßgröße die Gesamt-Phosphor-Konzentration verwendet werden. Nach den hohen Ausprägungen in der zweiten Hälfte der 70er Jahre ist die Konzentration bis 1993 stark rückläufig **(Abbildung A).** Auch unter Berücksichtigung des künstlichen Kapitals **(Abbildung B)** kann die Schlußfolgerung getroffen werden, daß der Trend in Richtung einer nachhaltigen Entwicklung geht.

Es folgt daraus eine „grüne" Ampel.

Abbildung A

Ges.-Phosphor-Konz. im steh. Gewässer (Bodensee)

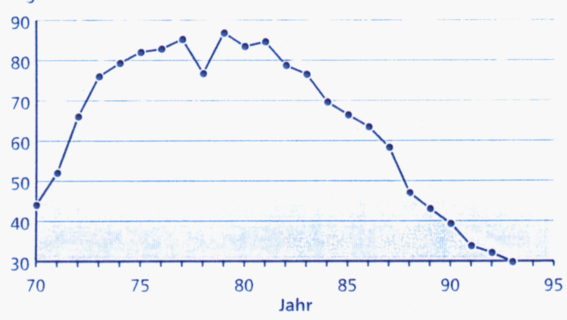
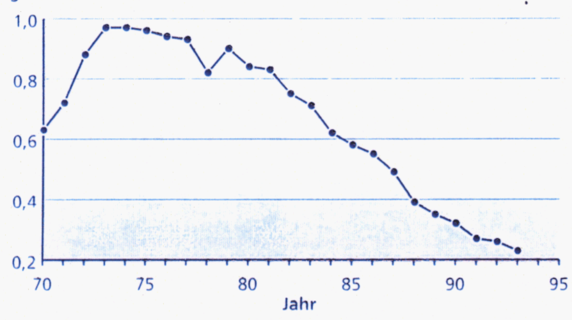
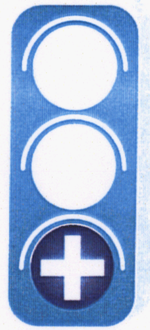


Abbildung B

Ges.-Phosphor-Konz. im steh. Gewässer pro NAV/Kopf



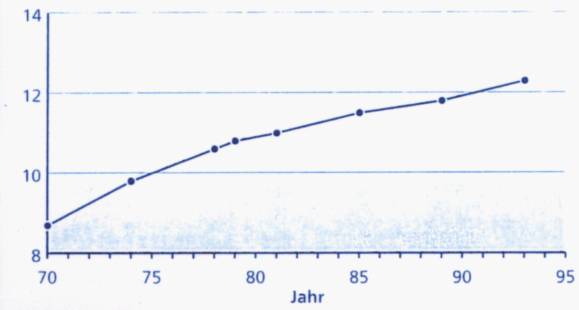


11. Boden

Der Boden wird hier in seiner Funktion als Standort beurteilt. Als Zustandsmeßgröße kann man dazu den Anteil der versiegelten Fläche an der Gesamtfläche verwenden. Mit dieser Meßgröße zeigt sich ein Verlauf, der sich von einer nachhaltigen Entwicklung entfernt **(Abbildung A)**. Unter Berücksichtigung des künstlichen Kapitals pro Kopf ergibt sich hingegen eine stetig fallende Linie **(Abbildung B)**. Dies bedeutet, daß der Anstieg des künstlichen Kapitals pro Kopf größer ist als die Abnahme der nicht-versiegelten Flächen. Folglich stehen potentiell Mittel zur Verfügung, um die Nutzeneinbußen durch den Rückgang des natürlichen Kapitals zu kompensieren. Weil dies auf eine höhere Ressourcenintensität der genutzten Flächen hindeutet, ist hier ein Trend in Richtung einer nachhaltigen Entwicklung denkbar.

„Gelb"

Abbildung A



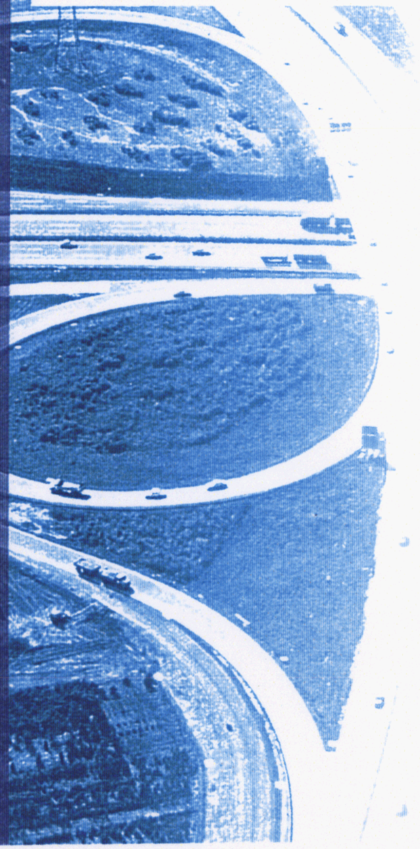


Abbildung B