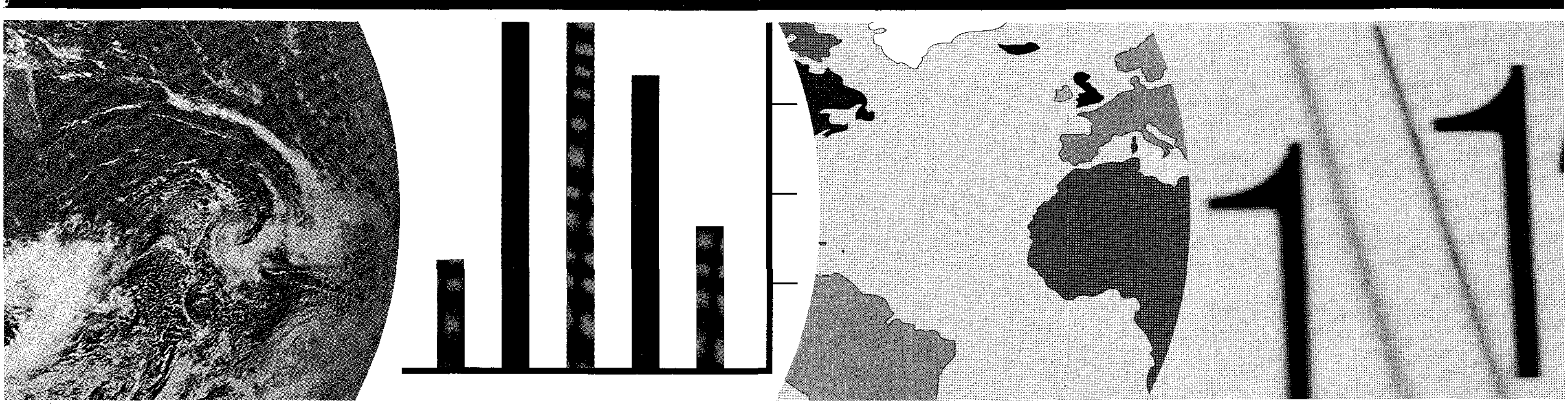

ENVIRONMENTAL INDICATORS:

A SYSTEMATIC APPROACH TO MEASURING AND REPORTING ON ENVIRONMENTAL POLICY PERFORMANCE IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

Allen Hammond
Albert Adriaanse
Eric Rodenburg
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WORLD RESOURCES INSTITUTE

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CONTENTS

LIST OF FIGURES

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FOREWORD

All across the United States, policy-makers and pundits sit up and take notice when the Dow Jones inches up, housing starts plummet, or unemployment rates rise—and millions of Americans rethink personal financial decisions. In every country, leaders find changes in gross national product (GNP) similarly riveting. These economic indicators show the power of a single number when its importance is widely understood. Yet, no remotely similar numbers exist to indicate how the environment is faring.

A significant attempt to bridge this knowledge gap is *Environmental Indicators: A Systematic Approach to Measuring and Reporting on Environmental Policy Performance in the Context of Sustainable Development* by Allen L. Hammond, director of WRI's Resource and Environmental Information program; Albert Adriaanse, senior ministerial advisor to the Netherlands' Directorate for the Environment; Eric Rodenburg, WRI senior policy analyst; Dirk Bryant, WRI policy analyst; and Richard Woodward of the University of Wisconsin. The authors begin by laying out a conceptual approach for producing "highly aggregated indicators"—that is, for turning mountains of data into a set of simple, significant, and user-friendly tools.

The authors note the special utility of environmental indicators in democratic countries, where electorates push governments to act on perceived problems. Indeed, they maintain, creating environmental indicators that the public can easily grasp is the surest way to compel high-level government attention—both to the environment and to the efficacy of policies for protecting or restoring it. Besides illustrating environmental trends, indicators can be designed to measure how well (or how poorly) policies work, implicitly pointing the way toward better approaches. In most countries, though, policy-makers and the public are equally in the dark when it comes to timely warnings about whether policies are taking the nation in the right direction.

There are exceptions, of course—most notably the Netherlands. As the authors demonstrate, the Dutch have made good use of indicators based on strong national goals to curb such environmental problems as ozone depletion, climate change, and acid rain. Since 1991, the Dutch government has published indicators showing how the nation's contribution to such problems has changed from one year to the next. When combined with targets for future performance, these indicators show Dutch citizens how effectively current policies are helping to improve both the Dutch environment and global conditions, and how far they have yet to go. As this report documents, the Dutch experience also shows that when conditions don't improve, indicators stimulate the search for improved policies.

WRI's experience also testifies to the efficacy of indicators as agents of change. In 1990, WRI's *World Resources* report published data showing an acceleration in the rate of tropical deforestation and summed up in a single indicator for each country—the Greenhouse Gas Index—the potential impact on global warming of both deforestation and fossil energy use. The results, admittedly controversial, attracted worldwide attention and helped to focus the efforts of scientists and government policy-makers on deforestation's possible role in climate change.

Environmental Indicators will not be the last word on this new field. On the contrary, it deliberately proposes bold ideas to spark dialogue on which data to compile and how to massage a mass of facts into a handful of meaningful numbers that signal whether environmental problems are getting better or worse. The authors acknowledge the work of others laboring in the field—not only the Canadian and Dutch governments and the Organization for Economic Cooperation and Development, but also a growing number of other institutions and university researchers. The United Nations Commission on Sustainable Development, for one, is exploring ways to create "sustainable development indicators;" so is the U.S. Government.

Dr. Hammond, Dr. Adriaanse, and their colleagues argue that *environmental* indicators are the best place to begin. They suggest that those they describe are good candidates to become the environmental components of sustainable development indicators some years down the road. But first things first, they say. Economic and social indicators already influence policy. What's utterly missing is a set of simple and unambiguous signals of how human activities are affecting the environment.

Environmental Indicators extends WRI's earlier work on indicators—including such reports as *Biodiversity Indicators for Policy-makers*—and the analyses set forth in our biennial series of *World Resources* reports. We are continuing our indicator research program, focusing on biodiversity and the coastal environment—critical resources for which we need better means of assessing our problems or our progress.

We would like to thank The Florence and John Schumann Foundation for an initial grant that enabled WRI to begin its indicator research, and express our appreciation to the U.S. Environmental Protection Agency, the Aeon Group Environment Foundation/Environmental Information Center-Japan, the Swedish International Development Authority, and the Netherlands Ministry for Foreign Affairs for continuing support of these efforts. We would also like to acknowledge the encouragement of this work by the United Nations Environment Programme. We are deeply grateful to this array of partners and sponsors for their assistance.

Jonathan Lash
President
World Resources Institute

I. INTRODUCTION

The term "indicator" traces back to the Latin verb *indicare*, meaning to disclose or point out, to announce or make publicly known, or to estimate or put a price on. Indicators communicate information about progress toward social goals such as sustainable development. But their purpose can be simpler too: the hands on a clock, for example, indicate the time; the warning light on an electronic appliance indicates that the device is switched on.

As commonly understood, an indicator is something that provides a clue to a matter of larger significance or makes perceptible a trend or phenomenon that is not immediately detectable. (A drop in barometric pressure, for example, may signal a coming storm.) Thus an indicator's significance extends beyond what is actually measured to a larger phenomena of interest.

Since the concern in this report is public policy issues and specifically the process of communicating information to decisionmakers and to the public, indicators are defined more precisely. Indicators provide information in more quantitative form than words or pictures alone; they imply a metric against which some aspects of public policy issues, such as policy performance, can be measured. Indicators also provide information in a simpler, more readily understood form than complex statistics or other kinds of economic or scientific data; they imply a model or set of assumptions that relates the indicator to more complex phenomena.

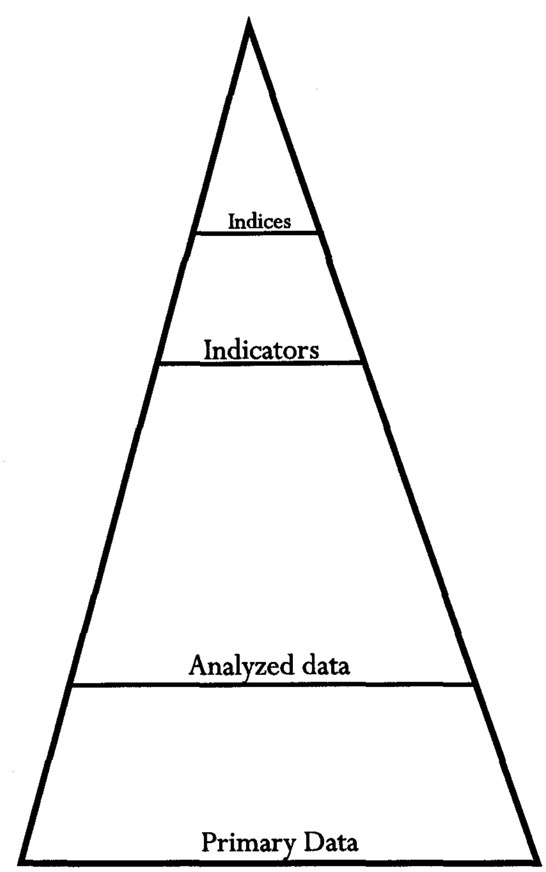
Those who construct indicators for public policy purposes have an obligation to make explicit both the metric and the underlying model inherent in them. As used in this report, indicators have two defining characteristics:[1]

- indicators **quantify** information so its significance is more readily apparent;
- indicators **simplify** information about complex phenomena to improve communication.

Even though indicators are often presented in statistical or graphical form, they are distinct from statistics or primary data. Indeed, indicators and highly aggregated indices top an information pyramid whose base is primary data derived from monitoring and data analysis. *(See Figure 1.)* Indicators represent an empirical model of reality, not reality itself, but they must, nonetheless, be analytically sound and have a fixed methodology of measurement.

Indicators also fulfill the social purpose of improving communication, but can play a useful role only where communication is welcomed, where decisionmaking is responsive to information about new social issues or the effectiveness of current policies. In an international context, the need for comparability in the way indicators are formulated

Figure 1. The Information Pyramid



and calculated becomes obvious. If every nation calculated GDP in a different manner, this indicator would be of little value.

Experience in public policy also illustrates several additional characteristics of successful indicators:

- **user-driven**. Indicators must be useful to their intended audience. They must convey information that is meaningful to decisionmakers and in a form they and the public find readily understandable. Similarly, they must be crafted to reflect the goals a society seeks to achieve.
- **policy-relevant**. Indicators must be pertinent to policy concerns. For the national-level indicators described in this report, policy-relevant means not just technically relevant, but also easily interpreted in terms of environmental trends or progress toward national policy goals.
- **highly-aggregated**. Indicators may have many components, but the final indices must be few in number; otherwise decisionmakers and the public will not readily absorb them. How much indicators should be aggregated depends on who is to use them and for what.

National-Level Indicators

Indicators can be used for many purposes at many levels—community, sectoral, national, or international. All are important, but in this report discussion is restricted to indicators that can support national or international decisionmaking. These indicators can guide national decisionmaking and focus top-level policy attention. Those gauging national performance explicitly can show citizens and decisionmakers alike whether trends are in the desired direction and, hence, whether current policies work. Indicators can also provide a framework for collecting and reporting information within nations and for reporting national data to such international bodies as the United Nations Commission on Sustainable Development. Indicators can provide guidance to those organizations on needs, priorities, and policy effectiveness.

The choice of indicators depends not only on the desired purpose—on the goals a nation seeks to achieve—but also on the audience. The indicators discussed in this report are intended to improve national policy and decisionmaking—specifically, the identification of environmental problems, policy formulation and target setting, and, especially, policy evaluation. The obvious audience comprises national and international decisionmakers. Since public opinion shapes democratic decisionmaking, the public is also an important audience for national performance indicators. Indeed, the power of economic and social indicators to shape public opinion compels high-level officials to take action when, for example, the GDP declines or the unemployment index rises.

Environmental Indicators in the Context of Sustainable Development

Since the United Nations Conference on Environment and Development in 1992, sustainability has become a widely shared goal. Although information can provide an improved basis for decisionmaking and gauging progress, accountability is possible only if goals and measures of progress are explicit. Appropriately formulated indicators—as defined in this report—can provide such measures, enhancing the diagnosis of the situation and making progress or stalemate obvious to all.

Sustainability involves—at a minimum—interacting economic, social, and environmental factors. Progress toward sustainability thus requires directing policy attention to all three. But analysts don't agree on whether existing economic and social indicators—such as GDP, the consumer price index, or the unemployment index—are useful measures of progress toward sustainable development and so far no consensus has formed on indicators of sustainable development. There is not even agreement on which conceptual framework is best for developing such indicators—a question raised later in this report.

That said, many highly aggregated economic and social indicators have been widely adopted and are frequently reported. They focus public attention and influence national and international policy decisions for better or worse. But there are virtually no comparable national environmental indicators to help decisionmakers or the public evaluate environmental trends or assess the effectiveness of national efforts to maintain environmental quality. True, *local* air quality indicators or smog indices of one kind or another are in common use in a number of industrial countries, but only a handful of indicators are widely adopted and systematically reported. Even the environmental indicators developed and compiled by the OECD are not routinely and publicly reported by national governments in most OECD countries or by most international development organizations. Consequently, environmental policy issues have often been overlooked at the highest levels of national and international decisionmaking,[2] and virtually nowhere is accountability for environmental decisionmaking as high as it is for economic and social issues.

This report attempts to lay a basis for environmental indicators in the context of sustainable development. It briefly surveys past efforts to develop such indicators and reports evidence that they can influence policy decisions. However, it also suggests that indicators based on conventional environmental data won't capture many environmental issues key to sustainable development and identifies the need for additional environmental indicators and for more highly aggregated measures. It suggests new approaches for formulating these indicators and illustrates how such approaches might be carried out. Nonetheless, this report is a work in progress: it also contains ideas and indicator concepts that are preliminary, in the hope that they will stimulate discussion and further work.

> ***Many highly aggregated economic and social indicators have been widely adopted, but there are virtually no comparable national environmental indicators to help decisionmakers or the public evaluate environmental trends.***

(The indicators proposed here can be understood as candidates for the environmental components of sustainability indicators. As such, their interaction with social and economic factors is important and is so noted in the text where links exist to specific economic sectors or social concerns.)

II. BACKGROUND AND CONTEXT

Growing concern over environmental issues in recent decades drives the need for more comprehensive and reliable environmental information. It has also generated "State of the Environment" efforts in many countries and in such international organizations as the U.N. Environment Programme to provide, analyze, and report on scientifically-based environmental information. Still neither decisionmakers nor the public have been able to easily interpret large quantities of new environmental data. To simplify information and thus to improve communication, the Canadian government began developing environmental indicator concepts in the late 1980s. In 1987, the Dutch government initiated similar work. After a G-7 Economic Summit in 1989, the seven economic powers asked the OECD to develop environmental indicators. Pioneering work by the Canadian and Dutch governments and by the OECD ensued.[3,4,5]

International interest in the environment and in sustainable development issues hit a new peak at the 1992 United Nations Conference on Environment and Development in Rio de Janeiro. The *Declaration of Rio de Janeiro on Environment and Development* emphasized the need for sustainability and for respect for the precautionary principle to protect the environment; *Agenda 21* called for the development of indicators. *(See Box 1., Formal Commitments at the Earth Summit.)*

WRI's involvement in environmental indicator research began in the late 1980s. In 1991, it surveyed more than 100 organizations and carefully reviewed the literature. At that time, it found that fewer than a dozen organizations were working on environmental or sustainable development indicators at a national or international level. In 1992, WRI organized and hosted an international workshop on environmental indicators to discuss concepts, methods, and tentative approaches; the attendees concluded that it was premature at that time to attempt a synthesis but pointed out the need for innovative approaches and experimentation.[6]

In 1993, WRI hosted Albert Adriaanse of the Dutch Ministry of Housing, Physical Planning, and Environment for a month's working visit that began a collaboration leading to this report. Later that year, the United Nations Statistical Division (UNSTAT) and the United Nations Environment Programme (UNEP) organized a Consultative Expert Group Meeting on Environmental and Sustainable Development Indicators in Geneva to survey the approaches to indicator development being pursued by many organizations. By 1994, the number of conferences and workshops on environmental or sustainable development indicators had grown enormously, as had the number of organizations pursuing indicator work; national or regional initiatives were launched in Europe (by the European Commission for Europe), in the United States, and in many other countries. Notable among more recent meetings was a technical workshop convened by the World Bank in late 1994 to find common ground on approaches to sustainable development indicators and, in early 1995, an international policy conference hosted by the Belgian and Costa Rican governments in connection with UNEP and the Scientific Committee on Problems of the Environment (SCOPE) to seek consensus on the need for and the uses of indicators internationally. The United Nations Commission on Sustainable Development (UNCSD) agreed that indicators of sustainable development would be discussed at its third session in 1995.

Parallel to these efforts were attempts to reform the GDP and other economic indicators to better take environmental concerns into account. Pioneering work at WRI and at the World Bank helped to launch what is known as environmental or "green" national accounting or as natural resource accounting,[7] which adjusts national economic accounts to reflect pollution costs and the depletion of natural resources. The basic idea in green accounting is that the depletion of nature's capital—natural resources—has a real cost to society and should be treated in national accounts in

Box 1. Formal Commitments at the Earth Summit

Principle 4 of the Rio Declaration states:

"In order to achieve sustainable development, environmental protection shall constitute an integral part of the developmental process and cannot be considered in isolation from it."

Principle 15 of the Declaration states:

"In order to protect the environment, the precautionary approach shall be widely applied by states according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."

Agenda 21 comments specifically on the need for indicators in Chapter 40:

"Indicators of sustainable development need to be developed to provide solid bases for decisionmaking at all levels and to contribute to a self-regulating sustainability of integrated environment and development systems."

This chapter also recommends that the United Nations system work with other relevant organizations to develop a harmonized set of indicators of sustainable development.

the same way as the depletion of economic capital assets. Support for this idea was immediate. It was endorsed in *Agenda 21*, which in Chapter 40 calls for "establishing systems for integrated environmental and economic accounting," and a proposed system of such accounts has been published by the United Nations Statistical Office as the System of Integrated Environmental and Economic Accounting or SEEA.[8] So far, no country has yet greened its GDP, even though preliminary studies of individual countries show that the GDP would be more accurate and useful if such environmental corrections were included. In any event, the SEEA accounts can also be used to calculate environmental indicators, as illustrated later in this report.

In addition to adjustments to economic indicators, purely economic approaches have been used to calculate measures of sustainability. Researchers at University College-London, for example, have developed widely used concepts of "weak" and "strong" sustainability.[9] *(See Chapter 9.)*

In recent years, the importance of "human capital"—human and social development—to overall development has been emphasized by the Human Development Index pioneered by the U.N. Development Programme.[10] So too, indicators of sustainable development must also reflect the degree to which human needs—including that for a safe, healthy, and productive environment—are met. Thus, measures of environmental impacts on human health and welfare are key to sustainability—either as environmental indicators or as components of social indicators. Equally important are measures of the degree to which exposure to pollution or access to clean water and clean air vary among social and economic groups, as discussed later.

III. HOW INDICATORS CAN INFLUENCE ACTION: TWO CASE STUDIES

THE DUTCH EXPERIENCE

The environmental policy performance indicators discussed in Chapter 5 have been published annually since 1991 by the Dutch government. These indicators have increased Dutch awareness of environmental issues, influenced policy decisions, and spurred planning efforts to reduce environmental pressures.

When first published, the indicators attracted considerable attention. Government officials, the private sector, and citizens all found such quantitative description of environmental trends intriguing. Initial discussions centered on the relevance of the trends presented and the methods used to quantify and construct the indicators. As they became accepted by decisionmakers and others as a proper model or representation of the pressures driving these environmental issues, the indicators began to exert a significant influence on policy-making; they were used to help set the policy agenda on environmental issues and to measure policy success or failure.

As users grew more familiar with the indicators and the methodology used to construct them, attention focused on the component pressures—whether specific gases or sectoral activities—that contributed to the overall trend described by a given indicator. They thus became a tool for setting detailed cleanup priorities. Users also began to use the whole information system—symbolized by the information pyramid *(Figure 1)*—interactively to assess the effects of proposed or planned policy measures on the trend of environmental pressures represented by the indicators. In short, the information system has become a kind of model for exploring alternative policies.

As one example, indicators have deeply influenced policy-making in the Netherlands on the issue of environmental acidification. Here, interest in the overall trend shown by the indicator—and the wide difference between current emissions and the level judged to be sustainable over the long term—prompted the Dutch government to set progressively stricter policy targets for reducing emissions of each of the primary acidifying gases (SO_2, NO_x, NH_3) covered by the indicator.

Interest in the overall trend shown by one indicator—and the wide difference between current emissions and the level considered sustainable over the long term—prompted the Dutch government to set progressively stricter policy targets.

A second example concerns the dispersion of toxics into the environment. Typically, targets for reductions in emissions are set in negotiations with the relevant economic sectors. As the indicator has helped the private sector to appreciate how its various activities contribute to the total burden of toxics released within the Netherlands, attitudes have changed. Recently, the Minister of Housing, Physical Planning, and the Environment and representatives of industry have signed voluntary agreements to significantly reduce toxic emissions. Welcome alternatives to regulation, these agreements harness the knowledge and creativity of the private sector in designing mitigation measures to meet policy targets. Such agreements are possible only with the industry's active participation and involvement—owed in large part to the visibility of the environmental indicators and the "transparency" of the information system on which they rest.

The construction and regular publication of environmental indicators related to policy performance in the Netherlands has helped it progress toward sustainability. By quantifying key trends and compressing enormous amounts of data into simple, comprehensible graphical indicators, this process has moved the policy debate toward specific mitigation measures and inspired additional policy measures where progress was limited. The Dutch experience has attracted wide interest in other countries.

WRI Experience—The Greenhouse Gas Index

In 1990, WRI published the first estimates of greenhouse gas emissions for all major countries.[11] Although background data were also given, the estimates were presented as an aggregated greenhouse index—an indicator that summed up for each country the overall impact on the atmosphere of its annual emissions of the major greenhouse gases. The estimates attracted widespread press attention and became very controversial, partly because the index allowed users to compare national emissions. Yet, they also helped provoke worldwide debate over the causes of such emissions, such as the combustion of coal, oil, and other fossil fuels and the clearing and burning of tropical forests, inspiring research, and influencing policy actions in several countries.

WRI has continued to publish the greenhouse index and to note trends in greenhouse gas emissions and their potential implications for climate change. With the passing of time, the controversy has faded: estimates once fiercely contested now attract no unusual attention. Indeed, countries that have signed the Climate Convention have committed themselves to calculate and report their own emissions. Yet, the controversy and subsequent changes in both received wisdom and public policies illustrate the power of indicators to communicate and to influence public discourse.

One source of the initial controversy was the methodology used to estimate the cumulative effects of greenhouse gas emissions on the atmosphere. In the absence of an established scientific methodology, WRI adopted a simple empirical method that differed from the method subsequently published by the Intergovernmental Panel on Climate Change, an international scientific collaboration. It later turned out, however, that the two methods yielded closely comparable results.[12] Indicators, as this report emphasizes, are a simplified model of reality, but in this instance the model was quite accurate.

A second source of controversy came from strenuous objections by Brazil to estimates of the rate of deforestation in that country, which made its total emissions high. The estimates came from an unpublished study done by a Brazilian scientific agency for the amount of deforestation in 1987—the year for which emissions were estimated for all countries, but also a year, as it happened, in which forest clearing and burning in Brazil were more extensive than ever before. The satellite technique used in the 1987 estimates was criticized as imprecise, and Brazil subsequently found a more reliable technique. On the other

Estimates of greenhouse gases attracted widespread press attention and became very controversial, partly because the index allowed users to compare national emissions. Yet, this indicator also helped provoke worldwide debate, inspiring research and influencing policy actions in several countries.

hand, even reducing the estimated deforestation in 1987 by 40 percent would not have significantly altered the result: Brazil would still have ranked among the highest three or four nations in greenhouse gas emissions that year. How much the public attention given deforestation rates after the greenhouse index was published affected Brazil's subsequent actions is uncertain, but new and tougher policies did combine with better enforcement and wetter weather, which reduces burning, to dramatically cut deforestation rates in subsequent years.

A third source of controversy was a complaint from the Centre for Science and Environment, an NGO in India. Analysts at the Centre used WRI's estimates of greenhouse gas emissions to calculate an alternative index of "excess emissions," taking into account the Earth's natural ability to sequester greenhouse gases and allocating this "global sink" to countries in proportion to their population size.[13] The Centre's index—and charges that more standard ways of calculating emissions represented "environmental colonialism"—engendered a debate over sinks and additional research on these poorly understood aspects of the carbon cycle.

As this experience illustrates, indicators that can capture complex environmental data in an easy-to-communicate form can heighten public awareness and inspire policy action.

IV. ORGANIZING ENVIRONMENTAL INFORMATION: INDICATOR TYPES, ENVIRONMENTAL ISSUES, AND A PROPOSED CONCEPTUAL MODEL TO GUIDE INDICATOR DEVELOPMENT

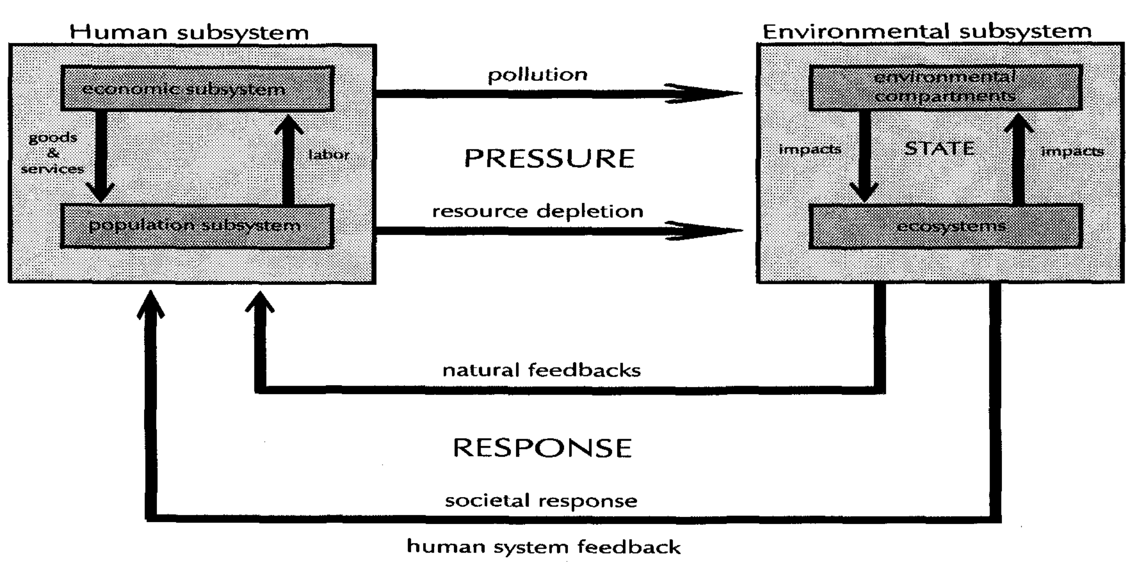
The goal of environmental indicators is to communicate information about the environment—and about human activities that affect it —in ways that highlight emerging problems and draw attention to the effectiveness of current policies. Indicators must tell us, in short, whether things are getting better or worse. To tell this story, an indicator must reflect changes over a period of time keyed to the problem, it must be reliable and reproducible, and, whenever possible, it should be calibrated in the same terms as the policy goals or targets linked to it.

PRESSURE, STATE, AND RESPONSE INDICATORS

Many human activities have environmental consequences, and these consequences can be numerous and wide-ranging. The information base used to build environmental indicators must span them all, so the data are sometimes confusing. For this reason, a conceptual framework is needed to structure diverse environmental information and to make it more accessible and intelligible to decisionmakers and the general public. Such a structure can also reveal data gaps, thus guiding data collection efforts.

A widely used framework for environmental indicators arises from a simple set of questions: What is happening to the state of the environment or natural resources? Why is it happening? What are we doing about it? Indicators of changes or trends in the physical or biological state of the natural world (state indicators) answer the first question, indicators of stresses or pressures from human activities that cause environmental change (pressure indicators) answer the second, and measures of the policy adopted in response to environmental problems (response indicators) answer the third. *(See Figure 2.)* More specifically, state indica-

Figure 2. Pressure-State-Response Framework for Indicators



tors measure the quality or "state" of the environment, particularly declines attributable to human activities. Examples include measures of stratospheric ozone concentrations, of urban air quality, or of stocks of fish. Pressure indicators, in contrast, show the causes of environmental problems: depletion of natural resources through extraction or overharvesting, releases of pollutants or wastes into the environment, and interventions such as infrastructure development or the conversion of natural ecosystems to other uses. In other words, these indicators measure environmental stress.

Response indicators gauge the efforts taken by society or by a given institution to improve the environment or mitigate degradation. Thus they measure how policies are implemented by tracking treaty agreements, budget commitments, research, regulatory compliance, the introduction of financial incentives, or voluntary behavioral changes.

This pressure-state-response framework, following a cause-effect-social response logic, was developed by the OECD from earlier work by the Canadian government. Increasingly widely accepted and internationally adopted, it can be applied at a national level (as in this report), at sectoral levels, at the level of an individual industrial firm, or at the community level.

Pressure indicators measure policy effectiveness more directly—whether emissions increase or decrease, whether forest depletion waxes or wanes, and whether human exposure to hazardous conditions grows or shrinks. Accountability for the pressures each country exerts on the environment is clear—as in the case of the amount of ozone-degrading gases emitted. These indicators are not only descriptive. They can also provide direct feedback on whether policies meet stated goals because they are based on measures or model-based estimates of actual behavior. Pressure indicators are thus particularly useful in formulating policy targets and in evaluating policy performance. They can also be used prospectively to evaluate environmental impacts of socioeconomic scenarios or proposed policy measures.

Response indicators measure progress toward regulatory compliance or other governmental efforts, but don't directly tell what is happening to the environment. As a practical matter, data to construct indicators is usually most available for pressure indicators and sparsest for response indicators.

FOCUSING ON ENVIRONMENTAL ISSUES

For practicality's sake, most efforts to develop environmental indicators have chosen to focus on a limited set of key environmental issues. The OECD, for example, compiles and reports indicators for eight environmental issues. The advantages of working from a common international list should be obvious, even though the importance of any single issue will vary by region or country.

To keep indicators as simple as possible, a single measure is usually selected for each major environmental issue. Often a considerable degree of aggregation is required. For instance, emissions

A widely used framework for environmental indicators arises from a simple set of questions: What is happening to the state of the environment or natural resources? Why is it happening? What are we doing about it?

of many greenhouse gases can be combined —through appropriate weights based on physical properties of the gases and models of their lifetimes in the atmosphere—to yield a single indicator of "equivalent" emissions. In a similar way, data on emissions of various nutrients that cause lakes and estuaries to eutrophy can be combined based on their chemical behavior, and measures of the depletion of various resources can be aggregated using economic valuation techniques.

Aggregation of similar data related to a single environmental issue is quite common, and, though experts can debate which weighting scheme to use, usually aggregation can be based on generally accepted scientific or economic principles.

Core lists of environmental issues—and of relevant indicators—have been and are being developed by several organizations, building on the OECD's initial work. Such indicators can be organized within the pressure-state-response framework into a matrix of indicators. Figure 3 is adapted from such a matrix under consideration by UNEP. Figure 4 shows a similar matrix adapted from one being considered by the World Bank.

Although they organize or structure environmental indicators (and have been extended to social and economic indicators as well), such arrays or matrices still provide an unwieldy amount of information. Accordingly, they may not simplify information enough for decisionmakers and the public. For this reason, a still higher level of aggregation or structuring is recommended: grouping environmental issues into a few broad categories based on a conceptual model of human-environment interaction. The indicators presented in this report give a preliminary sense of how such aggregation might work and what the result might be,

Figure 3. Matrix of Environmental Indicators

Issues	Pressure	State	Response
Climate Change	(GHG) emissions	Concentrations	Energy intensity; env. measures
Ozone Depletion	(Halocarbon) emissions; production	(Chlorine) concentrations; O_3 column	Protocol sign.; CFC recovery; Fund contrib'n
Eutrophication	(N,P water, soil) emissions	(N, P, BOD) concentrations	Treatm. connect.; investments/costs
Acidifcation	(SO_x, NO_x, NH_3) emissions	Deposition; concentrations	Investments; sign. agreements
Toxic Contamination	(POC, heavy metal) emissions	(POC, heavy metal) concentrations	Recovery hazardous waste; investments/costs
Urban Env. Quality	(VOC, NO_x, SO_x) emissions	(VOC, NO_x, SO_x) concentrations	Expenditures; transp. policy
Biodiversity	Land conversion; land fragmentation	Species abundance comp. to virgin area	Protected areas
Waste	Waste generation mun'pal, ind. agric.	Soil/groundwater quality	Collection rate; recycling investments/cost
Water Resources	Demand/use intensity resid./ind./agric.	Demand/supply ratio; quality	Expenditures; water pricing; savings policy
Forest Resources	Use intensity	Area degr. forest; use/sustain. growth ratio	Protected area forest, sustain. logging
Fish Resources	Fish catches	Sustainable stocks	Quotas
Soil Degradation	Land use changes	Top soil loss	Rehabilitation/protection
Oceans/Coastal Zones	Emissions; oil spills; depositions	Water quality	Coastal zone managment; ocean protection
Environmental Index	Pressure index	State index	Response index

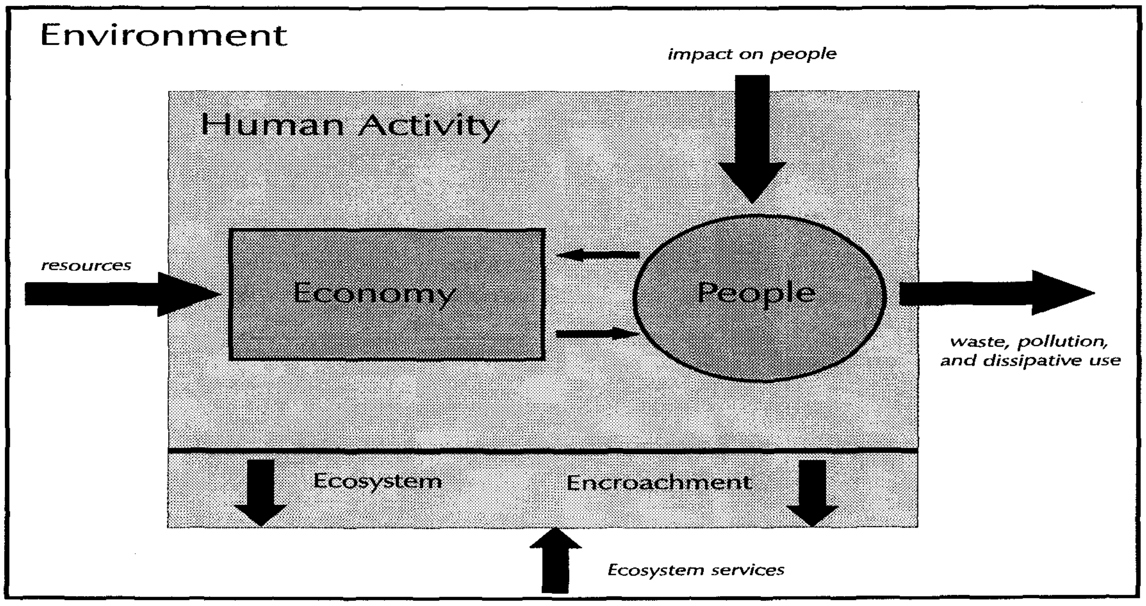
Source: OECD and UNEP

Figure 4. Matrix of Environmental Indicators

Issues	Pressure	State	Response
I. Source Indicators			
1. Agriculture	Value Added/Gross Output	Cropland as % of wealth	Rural/Urban Terms of Trade
a. Land Quality	Human-Induced Soil Degrad.	Climatic Classes & Soil constraints	...
b. Other	...	...	...
2. Forest	Land Use Changes, Inputs for EDP	Area, volumes, distribution; value of forest	In/Output ratio, main users; recyc. rates
3. Marine Resources	Contaminants, Demand for Fish as Food	Stock of Marine Species	% Coverage of Int'l Protocols/Conv.
4. Water	Intensity of Use	Accessibility to Pop. (weighted % of total)	Water efficiency measures
5. Subsoil Assets	Extraction Rate(s)	Subsoil assets % wealth	Material balances/NNP
a. Fossil Fuels	Extraction Rate(s)	Proven Reserves	Reverse Energy Subsidies
b. Metals & Minerals	Extraction Rate(s)	Proven Reserves	In/Output ratio, main users; recyc. rates
II. Sink or Pollution Indicators			
1. Climate Change	...	...	...
a. Greenhouse Gases	Emissions of CO^2	Atmosph. Concentr. of Greenhouse Gases	Energy Efficiency of NNP
b. Stratospheric Ozone	Apparent Consumption of CFCs	Atmosph. Concentr. of CFCs	% Coverage of Int'l Protocols/Conv.
2. Acidification	Emissions of SO_x, NO_x	Concentr. of pH, SO_x, NO_x in precipitation	Expenditures on Pollution Abatement
3. Eutrophication	Use of Phosphates(P), Nitrates(N)	Biological Oxygen Demand, P, N in rivers	% Pop. w/waste treatment
4. Toxification	Generation of hazardous waste/load	Concentr. of lead, cadmium, etc. in rivers	% Petrol unleaded
III. Life Support Indicators			
1. Biodiversity	Land Use Changes	Habitat/NR	Protected Areas as % Threatened
2. Oceans	Threatened, Extinct species % total	...	...
3. Special Lands(e.g.,wetland)	...	...	...
IV. Human Impact Indicators			
1. Health	Burden of Disease (DALYs/persons)	Life Expectancy at birth	% NNP spent on Health, vaccination
a. Water Quality	...	Dissolved Oxygen, faecal coliform	Access to safe water
b. Air Quality	Energy Demand	Concentr. of particulates, SO_2, etc.	...
c. Occupat'l Exposures,etc.	...	...	...
2. Food Security & Quality	...	...	...
3. Housing/Urban	Population Density (persons/km^2)	...	% NNP spent on Housing
4. Waste	Generation of industrial, municipal waste	Accumulation to date	Exp. on collect. & treatmt., recyc. rates
5. Natural Disaster	...	...	...

Source: The World Bank

Figure 5. A Model of Human Interaction with the Environment



thus illustrating the approach's feasibility. Highly-aggregated indicators, by compressing and simplifying information, communicate more effectively. If all the assumptions and sources of data are clearly identified, and the methodology is explicit and publicly reported, the index can readily be disaggregated to the separate components and no information is lost.

A Conceptual Model for Developing Environmental Indicators

Indicators are models of a more complex reality, and so are systems of indicators. The appropriateness of any model can be better judged if it is explicit. Here we propose an explicit conceptual model to guide the development of environmental indicators, acknowledging that it does not represent the only way to organize environmental information. *(See Figure 5.)*

This model describes four interactions between human activity and the environment:

- **source**: from the environment, people derive minerals, energy, food, fibers, and other natural resources of use in economic activity, thus potentially depleting these resources or degrading the biological systems (such as soils) on which their continued production depends;
- **sink**: natural resources are transformed by industrial activity into products (such as pesticides) and energy services that are used or disseminated and ultimately discarded or dissipated, thus creating pollution and wastes that (unless recycled) flow back into the environment;
- **life support**: the earth's ecosystems—especially unmanaged ecosystems—provide essential life-support services, ranging from the decomposition of organic wastes to nutrient recycling to oxygen production to the maintenance of biodiversity; as human activity expands and degrades or encroaches upon ecosystems, it can reduce the environment's ability to provide such services;
- **impact on human welfare**: polluted air and water and contaminated food affect human health and welfare directly.

For each of these types of interactions, composite indicators can be constructed. For instance, the source and sink type of interaction are closely related to organized economic activity and can be linked with specific sectors that play major roles. Economic sectors that withdraw materials from the environment include the managed ecosystems (agriculture, forestry, fisheries), energy, construction, and manufacturing (including mining). Pollutants, waste, and materials dissipation stem mainly from manufacturing (including mining), energy production and consumption, agriculture, the transport sector, and the municipal and household sectors. Environmental indicators for both source and sink interactions thus potentially contain important information about the sustainability of certain economic sectors; indeed, a source indicator can be stated in economic terms (namely, depletion) as well as physical terms. Chapters V and VI describe how highly aggregated sink indicators can be summarized in a composite **pollution index** and how the sustainability of resource use for many types of resources can be summarized in a **resource depletion index**.

The third type of interaction described in the model above is closely related to the ability of ecosystems to provide essential ecosystem services, including the maintenance of biodiversity. These issues are of growing importance—witness the international agreements formalized in the Biodiversity Convention—but almost no policy-relevant indicators exist. Chapter VII describes how such indicators for a central life-support function, maintenance of biodiversity, might be constructed from a geo-referenced database and summarized for each broad ecosystem type in a composite biodiversity measure, the **ecosystem risk index**.

The fourth type of interaction is concerned directly with environmental conditions that might affect human health and welfare. Closely related to social indicators, environmental indicators keyed to this interaction thus potentially contain important information about social conditions and development successes or failures. Such indicators could be summarized in an **index of environmental impact on human welfare**.

If the methodology described earlier is applied to this model, specific leading issues for each of the component interactions can be identified. In principle, indicators can be developed for each such issue to describe environmental pressures from human activity, the state of the environment, and the policy response. Here we focus on pressure indicators, partly because they best satisfy the criteria of policy-relevance and international commonality across countries and because they provide the basis for assessing policy performance. Nonetheless, state and response indicators may be immensely important, particularly in developing countries concerned primarily with identifying environmental issues and formulating environmental policies, or in international institutions trying to gauge their program effectiveness.

Box 2. Four Key Aggregate Indicators

- pollution
- resource depletion
- ecosystem risk
- environmental impact on human welfare

These indices track four broad types of human interaction with the environment. As such, they suggest a comprehensive yet easily comprehended basis for national reporting and policy evaluation. The four indices are aggregated from more than 20 primary environmental indicators, many of which are themselves aggregations of a number of similar data series—compressing a lot of information into a simple message. These four indices and their supporting indicators can be regarded as the environmental pressure element of a pressure-state-response matrix. They are also, we submit, a possible basis for assessing national environmental policies that is practical, covers the environmental concerns that are most critical to sustainability, and can easily be communicated to policy-makers and the public.

V. POLLUTION/EMISSION: ILLUSTRATIVE CALCULATIONS OF INDICATORS AND OF A COMPOSITE INDEX FOR THE NETHERLANDS

In human activities that treat the environment as a sink, what most needs to be measured are emissions, wastes, and dissipative uses of materials. Such activities can degrade the environment in various ways. Some create a global impact, others primarily a local or regional impact. Those pollution issues, important mainly because they affect human health and welfare, are discussed in a later chapter. So here the focus is on phenomena that primarily alter the character or health of the Earth's physical or biological systems. Climate change; depletion of the ozone layer; acidification of soils and lakes; eutrophication of water bodies; toxification of soils, water bodies, and ecosystems; and the accumulation of solid wastes all fall into this category. These problems are of importance in the Netherlands, but other countries may give highest priority to others.

Indicators for these six environmental issues are illustrated along the lines taken by the Netherlands.[14] They are measured in physical units. These indicators are already aggregated, since the environmental pressures for each of the six all stem from emissions or releases of more than one material or substance. Because the environmental effects of the components of a given indicator vary, each type of contributing emission must be appropriately weighted before emission can be totalled or aggregated to create an overall indicator for a given issue. Halon 1301, for instance, damages the ozone layer more than ten times as much as the reference substance CFC-11 and is weighted accordingly. Based on comparable weighting principles, a unit of measure has been developed for each issue—an ozone-depletion equivalent, for example. When the contributions of each component are expressed in these units, the effects of each can be compared and then summarized in a single indicator.

The selection of contributing substances for a given indicator is based on a compromise between the need for completeness and the need for simplicity in methodology and in data collection. In practice, only the principal contributing substances are selected for each issue, though it is important to check that the indicator is sufficiently representative and that no major factor has been neglected.

The indicators are presented to be self-explanatory. Each consists of a single graph—showing the course of the total environmental pressure measured by the indicator over time—one or more policy targets, and a single percentage, which is the percentage reduction in the pressure required to reach the target. In the graph, the pressure indicator and the policy target for that issue are expressed in the same units, such as ozone-depletion equivalents.

CLIMATE CHANGE

Emissions of greenhouse gases alter the composition of the Earth's atmosphere so that it traps additional heat radiated by the earth, thus increasing the likelihood of global warming. The main greenhouse gases released by human activities are carbon dioxide, methane, nitrous oxide, chlorofluorocarbons (CFCs), and halons. Emissions of any of these substances increase the atmosphere's warming potential.

How much emissions of greenhouse gases add to the potential for global warming depends on how long they remain in the atmosphere before being removed or breaking down into other compounds and on how well they absorb the heat radiated by the earth. These two factors are combined in the Global Warming Potential (GWP) for each gas, which is used as a weighting factor for emissions of that gas. The weighted summation of the Dutch annual discharge of CO_2, CH_4, N_2O, and the Dutch use of CFCs and halons, expressed in CO_2 equivalents, forms the indicator for climate change. In 1980, the Dutch contribution to

Figure 6. Climate Change Indicator

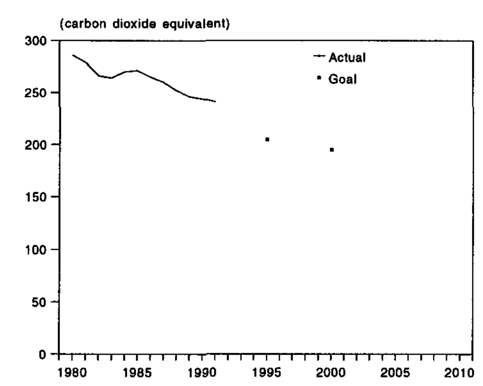
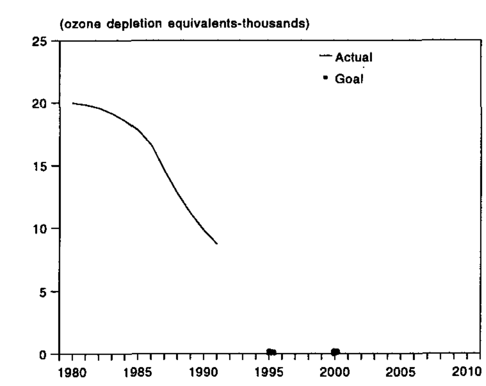


Figure 7. Ozone Depletion Indicator



the greenhouse effect was approximately 286 of these units; in 1991, approximately 239, a decline of 16 percent in environmental pressure caused by the discharge of greenhouse gases in the Netherlands. The trend of the climate change indicator is shown in Figure 6.

The aim of the Dutch policy is to reduce the 1988 discharge levels of greenhouse gases by more than 50 percent by the year 2020. The near-term policy targets are to reduce emissions to 205 CO_2 equivalents by 1995 and to 195 by the year 2000.

DEPLETION OF THE OZONE LAYER

The ozone layer blocks ultraviolet rays that are harmful to people, flora, and fauna. Its depletion is caused by pollution of the stratosphere by substances that catalyze the decomposition of ozone (O_3). When this happens, ultraviolet radiation increases. The compounds most damaging to the ozone layer are chlorofluorocarbons (CFCs) and halons, which may take 10 to 15 years to reach it once released.

How damaging these ozone-depleting compounds are depends on how long they reside in the atmosphere and how readily their constituent chemicals react to break down ozone. These two factors are combined in an Ozone Depletion Potential for each gas, which is used as a weighting factor for emissions of that gas. The weighted summation of the Dutch use of CFCs and halons, expressed in ozone-depletion equivalents, forms the indicator. In 1980, Dutch use and, consequently, emissions, were estimated to be 20,000 of these units. By 1991, it had dropped to 8,721 units, a 56 percent decline in environmental pressure from the emission of ozone-depleting substances. This trend in the ozone depletion indicator is shown in Figure 7.

The Dutch policy target is nearly complete termination of production of ozone-depleting substances—to a level of 54 ozone-depletion equivalents—by 1995. By the year 2000, the target goal is zero production. The assumption here is that the use and, consequently, the emissions of CFCs and halons will follow the same trend as their production.

ACIDIFICATION OF THE ENVIRONMENT

Air pollution by substances that form acids acidifies the environment. Acid deposition can directly damage buildings, materials, and plants. Indirect damage occurs via acidification of the soil. The three main acidic substances are sulphur dioxide, nitrogen oxides, and ammonia; other acidic components and ozone are not incorporated in the indicator.

The potential environmental damage from acidifying substances that are deposited in the soil

Figure 8. Acidification Indicator

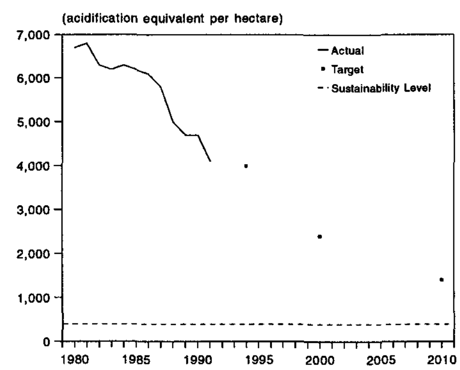
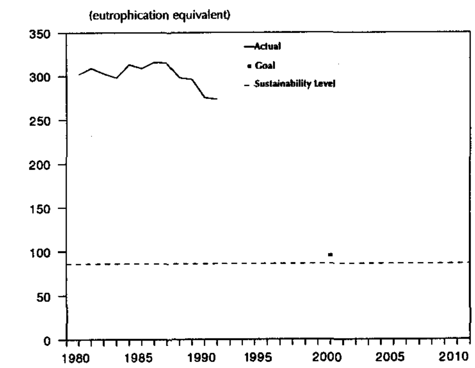


Figure 9. Eutrophication Indicator



is expressed in units of acidification equivalents per hectare per year. In 1980, deposition consisted of 6,700 units; in 1991, the comparable figure was 4,100, reflecting a decline in the environmental pressure from acidification of 39 percent. This trend in the acidification indicator is shown in Figure 8. Both foreign and domestic sources contribute to acid deposition; in 1980 and 1989, Dutch sources contributed 48 percent and 54 percent, respectively, of total acidic deposition in the Netherlands.

The policy target set by the Dutch government is to reduce deposition to 4,000 acidification equivalents by 1994, to 2,400 units by 2000, and to 1,400 units by 2010. The sustainability level, or the long-term target, is estimated to be 400 acidification units. These targets relate to the total deposition, which includes the foreign contribution.

Eutrophication of the Environment

Eutrophication of the environment occurs when an excessive supply of plant nutrients disrupt ecological processes in water bodies or in soil. One manifestation of eutrophication is an undesirably large quantity of algae in ponds and lakes, which leads to a shortage of oxygen. Plant species that thrive in low-nutrient environments often disappear as a result of eutrophication—one reason why heaths or peat bogs are becoming increasingly overgrown with grass. In addition, nitrate levels in groundwater are now so high that drinking water supplies are under threat. Phosphates and nitrogen compounds are the primary substances that cause eutrophication; in the Netherlands, the principal sources are manure, fertilizer, wastewater, sewage sludge, dredge spoil, and solid waste.

Releases of phosphates and nitrogen compounds to the environment can be expressed in units of eutrophication equivalents. In the indicator, only releases from Dutch sources are included. In 1980, such releases totalled 302 units; in 1991, the amount was 273 units, a decline of 10 percent in environmental pressure resulting from the discharge of the two main eutrophying substances. The trend in the eutrophication indicator is shown in Figure 9.

The Dutch policy objective is to restore the balance between the supply and removal of phosphates and nitrates in water and soil so as to safeguard the natural processes. The target for the year 2000 is calculated to be 95 eutrophication equivalents.

Dispersion of Toxic Substances

Many chemicals, heavy metals, radioactive substances and other toxic or hazardous substances

Figure 10. Toxics Dispersion Indicator

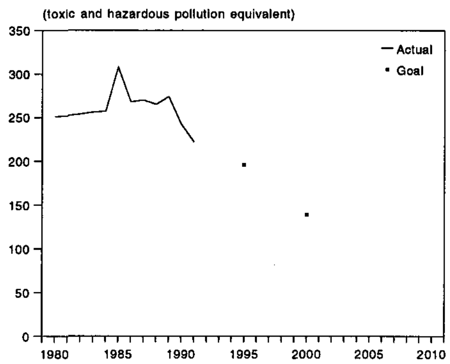
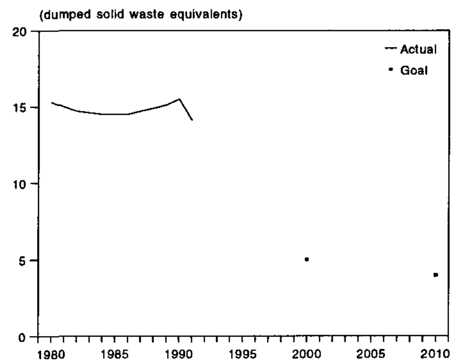


Figure 11. Solid Waste Disposal Indicator



are released to the environment in industrial pollution or waste or in consumer products. Some toxic materials, such as pesticides, are deliberately dispersed into the environment.

The indicator for dispersion focuses on releases of three main categories of substances: pesticides, radioactive substances, and priority substances (chemical and heavy metals deemed to pose the greatest risks). A distinction is made between agricultural and non-agricultural uses of pesticides; only the former is included in the indicator. Releases are weighted according to their toxicity and their longevity in the environment and measured in units of dispersion equivalents. In 1980, the total quantity of substances released into the environment was estimated to be 251 units; in 1991, this quantity had fallen to 222 units, a decline in environmental pressure from toxic dispersion of 11 percent. The trend in the toxic dispersion indicator is shown in Figure 10.

The Dutch policy objective is to reduce the quantity of each of the hazardous substances released into the environment to a level at which the risk posed by each substance is negligible. Reduction targets have been set for each category of substances. The policy target calculated on this basis is to reduce releases to 196 dispersion equivalents by the year 1995 and to 139 units by the year 2000.

Disposal of Solid Waste

The disposal of solid wastes involves collection, treatment, processing, recycling, reuse and incineration, discharge, and dumping. Here disposal is represented as the total quantity of solid waste dumped annually, apart from dredge spoil, manure, phosphoric acid gypsum, and polluted soil. Dumped residues from waste-incineration plants are included. The dumped quantity is expressed in waste equivalents in millions of tonnes per year. In 1980, an estimated 15.3 such units were dumped in the Netherlands, and 14.1 units in 1991. The trend in the waste disposal indicator is shown in Figure 11.

The Dutch policy objective is primarily to prevent the creation of waste products. Where waste products exist, the goal is first to bring about a shift from dumping and incineration to recycling (in the same production chain) and reuse (in another production chain). The waste disposal policy target for the year 2000 is 5.0 waste equivalents.

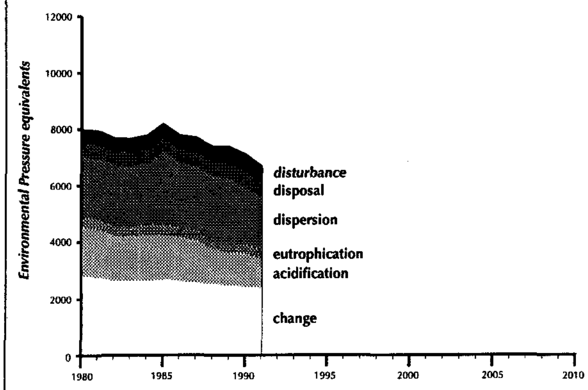
Composite Pollution Index

These six indicators—already highly aggregated—can be further aggregated into a *composite pollution index*, representing the overall pressure from the use of the environment as a sink. To do so requires aggregating unlike quantities. This is done by weighting each environmental issue on the basis of the gap between the current value of the indicator and the long-term policy target for sustainability: the greater the gap, the larger the weight assigned. Figure 12 shows a composite pollution index calculated on that basis for the Netherlands and incorporating six indicators, each measured in units of environmental pressure equivalents.[a] The overall trend shows a decline in environmental pressure from 1980 through 1991.

The trend in the individual indicators or in the composite pollution index over time provides a strong measure of whether actions to reduce the pressures on the environment are moving the Netherlands toward or away from its goals for sustainability. A comparison of such an index across comparable countries on a per capita or per GNP basis would suggest where the intensity of pollution is most severe.

Although the specific pollution or emission-related problems that are most important will differ from country to country, the methodology employed here can be used to develop appropriate indicators of the environmental pressures arising from other pollution problems. As the Dutch examples illustrate, the indicators greatly compress and simplify data on environmental pollution, making the trends comprehensible to policy-makers and the public. The composite pollution index provides an even greater degree of simplication and a corresponding ease of communication about the overall effectiveness of a country's environmental policies in reducing pollution.

Figure 12. Composite Pollution Index



[a] In the composite index shown here, an indicator for environmental disturbance from odor or noise has been used instead of the ozone depletion indicator discussed above.

VI. RESOURCE DEPLETION: ILLUSTRATIVE CALCULATIONS OF COMPOSITE INDICES FOR SELECTED COUNTRIES

The key issue for human activities based on natural resources is the sustainability of resource extraction or production. Extraction of subsoil minerals and of energy minerals depletes the resource; by definition, it can't be sustained indefinitely. On current evidence, many renewable resources (or the biological base that sustains them) are also being depleted. Managed ecosystems (agriculture, forests, and fisheries) and groundwater systems are especially threatened in many locations. For example, erosion, micronutrient depletion, compaction, or the excessive use of pesticides are taking a widespread toll on soil fertility. In principle, forests can be harvested sustainably, but all too often they are simply cleared, fragmented, or cut excessively. Many groundwater resources are being pumped or degraded by pollution, far faster than they can be replenished. Overfishing has severely depleted stocks in many marine fisheries and may have permanently degraded the productivity of some.

These indicators directly measure the sustainability of natural resource use, so they signal the effectiveness of natural resource policies— especially important for economies dependent on such resources.

Resource depletion can be measured in physical and in economic units. Mineral resources are usually quoted in physical units, and many indicators of fisheries depletion and other renewable resource depletion are also stated in physical units. Here, however, we illustrate two versions of a composite index based on economic units, which permit easy aggregation of various resources.

The indices illustrated here use the methodology of natural resource (or "green") accounting.[15] Rather than seeking to modify the value of the GDP, however, the methodology is used here to create highly aggregated indicators of resource depletion. These indicators directly measure the sustainability of natural resource use and thus provide a signal of the effectiveness of natural resource policies that may be especially important for economies dependent on such resources.

The *index of resource depletion* proposed here measures the value of the decline in natural resource stocks in a country relative to the value of gross (or net) investment in man-made capital during the given year. Roughly speaking, the index indicates the degree of departure from sustainable resource use, assuming that the depletion of natural resources is sustainable if their use leads to the creation of other assets of equal value. In the language of the economics of sustainable development, this is an assumption that natural resource assets can be substituted by fixed assets if society's total capital does not decrease as a result (so-called "weak sustainability").[16]

The index is normalized so that an index of one indicates that the increase in man-made capital is offset exactly by the depreciation of the nation's natural assets. An index much less than one indicates that resource depletion is small compared with the increase in man-made assets (a desireable circumstance); an index greater than one indicates that resource depletion exceeds the formation of man-made capital (evidence of unsustainable development). A negative value indicates the development or discovery of new resources.

The data used to generate the index come from fifteen separate natural resource or environmental accounting studies and from the standard national economic accounts. *(See Appendix 1.)* Environmental accounting, a relatively new methodology, has been implemented only on a trial or illustrative basis and only in a few countries. The United Nations Statistical Office's new handbook for Integrated Environmental and Economic Accounting proposes a System of Environmental and Economic Accounts (SEEA) which amounts to a framework for describing natural resource depletion in "satellite" accounts that parallel the conventional national economic accounts.[17]

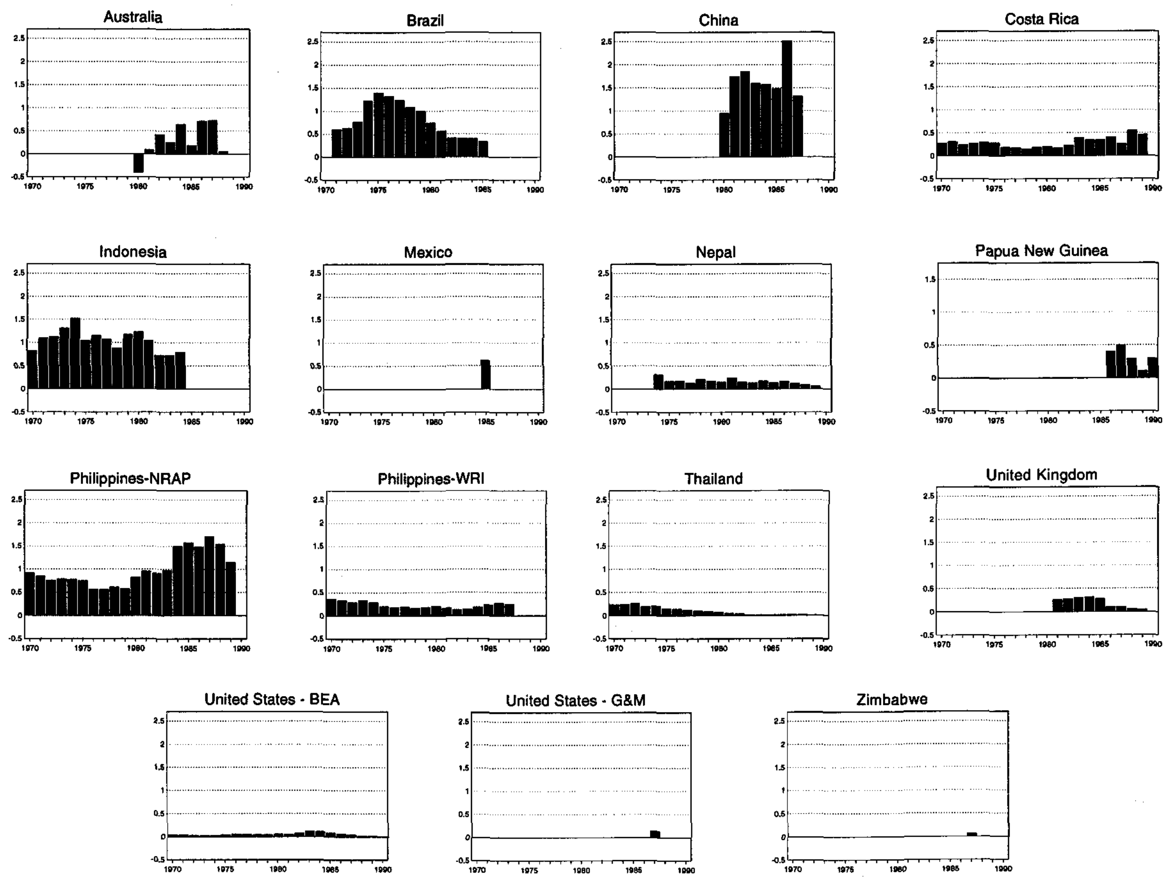
Because most efforts to carry out natural resource accounting will probably follow the proposed UN system, the index illustrated here is based on that framework. Most natural resource accounting studies implemented to date correspond to a particular version of the SEEA (described in the UN handbook as Version IV, which extends the boundary of measured economic activity far enough to take renewable resource depletion into account). An important issue in such studies is how changes in resource stocks are measured. If the resource is bought and sold directly, stock changes can be valued by standard, market-based methods. But if the resource is not directly bought and sold in markets, less standard and more controversial methods must be used. Because of differences in methodology and similar differences in the range of resources included in the studies, *the resource-depletion estimates summarized in this illustrative index are not directly comparable across countries* (or even across studies for the same country). Comparability can come only when the SEEA is implemented consistently. Nonetheless, for the purpose of illustrating how an index based on the SEEA could be developed, the *index of resource depletion* presented here includes all resource-depletion estimates developed in the original studies.

Further qualifications are necessary. With three exceptions, the natural resource accounting studies on which the index illustrated here are based did not develop and present data in a manner consistent with the SEEA. It was thus necessary to recalculate resource depreciation using raw data from the studies. Also, the original studies include significant caveats regarding their credibility and precision. (None has been published as an official government document.) Given these qualifications, the index described here must be seen as illustrative only and cannot be used to draw conclusions about one country as compared to another.

The trend of resource depletion over time within a given country is not subject to the qualifications described above, but other caveats hold in interpreting these trends. As applied in most studies to date, the level of resource depreciation is highly sensitive to prices. Even after adjusting for inflation, the depreciation in one year might differ substantially from that in the following year because of price changes from one year to the next. The present system of national economic accounts avoids these problems by establishing a base-year value, so year-to-year changes in economic measures reflect changes in the physical quantities consumed or produced, not price fluctuations. If this practice were extended to the SEEA, then annual variation in the proposed index of resource depletion would reflect only the changes in the physical depletion of the resource base.

With these qualifications, however, the illustrative calculations of the resource depletion index for some fifteen countries show some interesting patterns. *(See Figure 13.)* In Australia, for example, fixed capital formation appears to outweigh the depletion of mineral stocks and soils, though the trend is to ever greater depletion. In Brazil, on the other hand, after a brief excursion into unsustainable territory (when the depletion of mineral and forest resources seemed to exceed fixed capital formation), the trend has been toward relatively less resource depletion and, hence, toward more sustainable practices. In the Philippines, two studies focused on different resources and came to different conclusions about the extent of resource depletion relative to fixed capital formation. In Indonesia, the depletion of oil, forest, and soil resources appears to fluctuate relative to fixed

Figure 13. Resource Depletion Index: Resource Depreciation/Gross Fixed Capital Formation

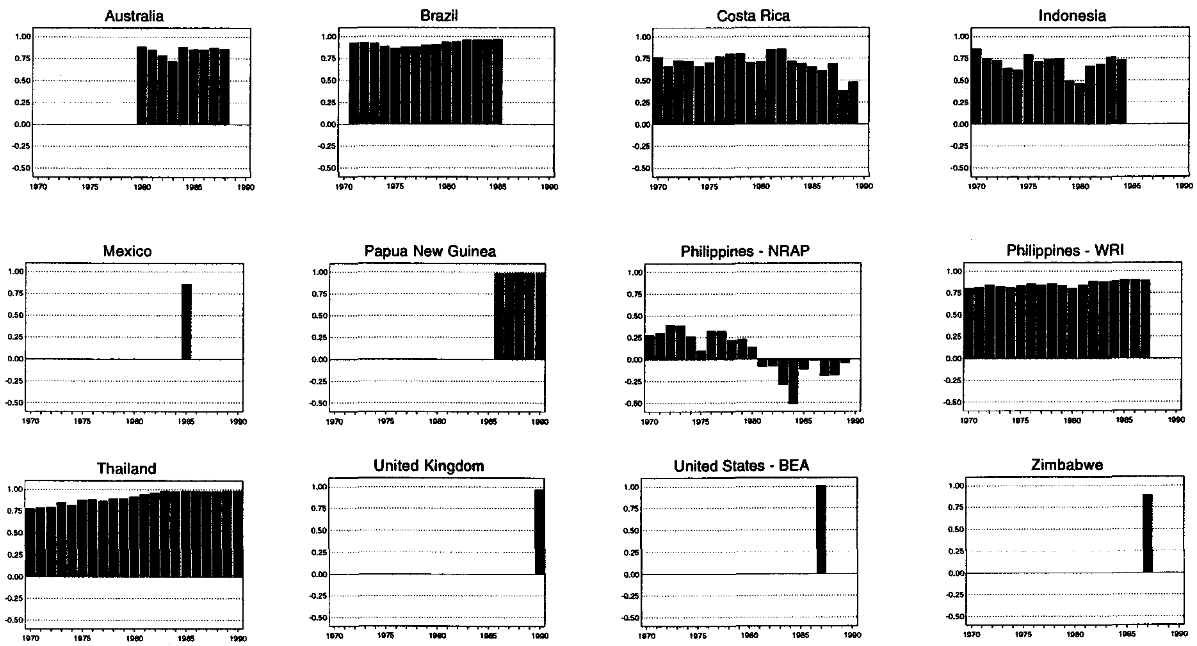


capital formation, but the trend is toward increasing sustainability. In China, the depletion of coal, iron, and the city of Beijing's groundwater resources appears to be greater than fixed capital formation, though the trend is toward increased sustainability.

The index of resource depletion is macro-economic, representing the overall role of resources in the economy. If fully implemented, the SEEA framework enables analysts to calculate comparable indices for any given economic sector. This disaggregation of the index by sector could be particularly important in developing or monitoring the effectiveness of sectoral policies. Figure 14 illustrates this disaggregation for the major renewable resources, giving the ratio of the environmentally adjusted domestic product for agriculture, forestry, and fisheries combined to the standard GDP for these resource sectors. This ratio shows whether the sector is operating sustainably or not. Here, a value of one means essentially no depletion; a value much less than one suggests that most of the sector's product comes at the expense of natural resources, and a negative value indicates depletion even greater than output; a value greater than one, on the other hand, indicates that growth of stocks more than compensated for harvesting or that the resources had otherwise increased in value during the year.

The patterns in Figure 14 show wide variation. In Australia, Brazil, Thailand, and (in one study) the Philippines, the renewable resources assessed are only slightly depleted. In another study of somewhat different resources, depletion in the Philippines appears high, exceeding sector output toward the end of the period studied. Depletion

Figure 14. Resource Depletion Index: Resource Depreciation/Sector Domestic Product (Agriculture-forestry-fisheries sector)



appears to fluctuate in Indonesia and Costa Rica, with an overall trend toward higher depletion.

Because the SEEA accounting practices have not been implemented, the indices illustrated here could not now be routinely calculated. In principle, however, the depletion indicators described here can be calculated from the SEEA and a resource depletion index could be calculated in physical units for many countries. The point is to illustrate the potential of resource-depletion indicators to help decisionmakers and the public to better assess policy effectiveness and the sustainability of natural resource use. The trends revealed by such indicators over time show whether natural resource use is becoming more or less sustainable. A multi-country comparison of a comparable resource depletion index could suggest where depletion is most severe. A natural target is suggested by the structure of the index, either no net depletion (for "strong sustainability") or no depletion in excess of the creation of fixed assets (for "weak sustainability"), but specific targets would depend on national policies yet to be adopted.

VII. BIODIVERSITY: AN ILLUSTRATIVE APPROACH TO THE DEVELOPMENT OF COMPOSITE INDICATORS

Nature provides many services necessary to the support of all life. So-called ecosystem services range from oxygen production to water purification, nutrient recycling, and maintenance of biological diversity, among others. In our model of how human activities interact with the environment, indicators of biodiversity are a proxy for measures of fundamental life-support functions. Focusing on biodiversity also serves the emerging need for methods of national monitoring and reporting under the Biodiversity Convention.

The diversity of life is reflected at the levels of genes, species, and ecosystems. Although all three reflect important elements of Earth's biological heritage, many of the interactive processes critical to all life take place at the ecosystem level. Thus, while biodiversity can in some sense be measured on a species level by counting species or listing endangered species, policies to preserve biodiversity must of necessity aim higher—at the ecosystem or habitat.

> ***While biodiversity can in some sense be measured by counting species or listing endangered species, policies to preserve biodiversity must aim higher —at the ecosystem or habitat.***

Another reason to take this approach is that ecosystems correspond at least roughly to geographical units for which administrative responsibility for conservation and land management activity can be assigned. In addition, it is far easier to monitor how changes in many human activities—such as cutting of forests—affect ecosystems than to monitor populations of species.

At present, virtually the only widely reported indicators pertinent to biodiversity are lists of endangered species (a state indicator), statistics on the amount of wilderness area (also a state indicator showing the absence of human activity), or statistics on the percentage of land accorded various degrees of protection (a response indicator). None of these measure the pressures on ecosystems from human activities. Human activities that encroach upon or degrade ecosystems (ecosystem pressures) and measures of an ecosystem's ability to maintain biodiversity or provide other ecosystem services (ecosystem condition or state) perforce vary significantly from one area to another, even within the same ecosystem. For these reasons, *national* measures of biodiversity of use to policymakers may be impossible to compile unless they are based on spatially referenced data—essentially, digital maps. Such maps, featuring the spatial distribution of vegetation types or other markers of broad ecosystem type, basic physical data on land type and microclimate, as well as the location and intensity of various human activities, represent a novel but increasingly important kind of primary data. We suggest that such data constitute the essential information base needed to construct meaningful biodiversity indicators. Fortunately, increasingly sophisticated Geographic Information System (GIS) techniques allow researchers to manipulate and interrelate digital maps. The biodiversity indicators proposed here, then, consist of summary national statistics extracted from digital maps and the interrelationships among them. Concrete examples might be the percentage of wetlands at high risk of biodiversity loss, or a graph showing the trend over time of total pressures on forests.

Human activities that directly pressure ecosystems include destruction of habitats or conversion of land to other uses—say, clearing of forests or filling in wetlands; overharvesting, e.g. of firewood or overgrazing of domestic animals; introducing exotic species; or polluting or diverting water. Some of these activities are not easily measured and can only be estimated on the basis of such indirect measures as human population distribution or the presence of roads and other infrastructure. Others can be measured, and many countries already posses relatively good spatial data on them. Superimposed digital maps of such variables crudely show the distribution of pressures on ecosystems.

Information on the pattern of pressures on an ecosystem and their trend over time can speak volumes in itself. But the same level of pressure—a stocking density of one cow-equivalent per hectare in grasslands, for example—may have little or no effect in one area but may exceed local biological thresholds and alter the species mix in another. Thus, an ecosystem's inherent sensitivity to human disturbance and its heightened sensitivity as degradation worsens also help determine its vulnerability to further degradation. In terms of ecosystem services, this vulnerability translates into the risk that the ecosystem will be unable to maintain biodiversity.[18] Measures of inherent sensitivity include the distribution of geophysical and biological parameters (such as soil type, climate zones, slope, and proximity to waterways); and the current degree of modification in the area (whether habitat fragmentation or soil erosion, for instance). Combining pressure and sensitivity data—by interrelating digital maps through algorithms that reflect the regions' ecological thresholds—can show the relative risk of degrading biodiversity throughout an ecosystem. Such measures, either in map form or as summary national statistics compiled from it—an ecosystem risk index indicating the percentage of area at high risk—would give decisionmakers a more sophisticated and useful indicator than uncalibrated pressure data alone can.

The trend over time of summary statistics drawn from a digital map of ecosystem risk would provide a strong measure of whether the pressures of human activity are undermining a nation's biodiversity. A comparison—by country or by major ecosystem type—of such indicators across a region would suggest where the risks are most severe.

Targets for such indicators would need to be set in conjunction with the Biodiversity Convention and by individual nations. Indeed, such indicators and the digital maps used to calculate them could form the basis for national policy action and reporting under the Biodiversity Convention. Meanwhile, development planners and others eager to improve the sustainability of land use and land management practices should find these maps invaluable. At any rate, efforts to develop such map-based indicators of ecosystem risk can serve several information purposes.

Such efforts are already afoot. Similar map-based tools have been developed by the U.N. Food and Agriculture Organization to guide agricultural planning and by the U.S. Forest Service to assess fire risk.[19] Digital maps showing population distributions and existing infrastructure are already being compiled for most countries in Africa and provided to those countries for checking and local use as a development planning tool.[20] Building on that effort, the World Resources Institute is working with the World Conservation Monitoring Centre, RIVM, Conservation International, and the Institute for Sustainable Development to collect expert knowledge and to prepare preliminary pressure, sensitivity, and ecosystem risk maps for a few countries in Africa.[21] The digital maps and the indicators calculated from them will then be evaluated by experts and potential users in the mapped countries. In short, although it's too early to assess the utility of ecosystem risk indicators, composite biodiversity indicators seem both feasible and promising.

VIII. HUMAN IMPACT/EXPOSURE INDICATORS

Many forms of environmental pollution or of natural resource degradation are important because they directly affect people. Sanitation problems, such as polluted drinking water, are a major cause of human disease; urban air pollution and exposure to environmental disease vectors also impair health. The key questions here thus concern human welfare, the environmental conditions that undermine it, and the social equity of how involuntary exposures to such environmental pressures are distributed among people.

The component issues of the overall index proposed here include drinking water pollution, air pollution, environmental disease vectors, contaminated food, inadequate housing, and occupational exposures to toxics. Typically, such conditions vary widely within a country and affect some people but not others, so that, for example, measures of air pollution in a few cities do not provide a useful national index. In the indicators proposed here, the degree of exposure is weighted by the population exposed. Thus, data on the number of days on which ambient concentrations of major air pollutants—sulfur dioxide, ozone, carbon monoxide, particulates, and lead—exceed WHO standards might be multiplied by the number of people exposed, city by city, to give a national impact number. Other indicators can reflect the size of the populations exposed to substandard drinking water, living in substandard housing, exposed to toxic substances on the job, or exposed to food supplies contaminated by pesticides or heavy metals.

Further discussion is needed to establish a consensus on how to measure social equity in environmental exposures. (For instance, should exposure be correlated to income or to other relevant social groups?) Hence no prototype indicators are included here. That said, such indicators and their aggregate, a composite index of environmental impact on human welfare, could be profoundly important in many developing countries. Indeed, their trend over time could provide a measure of whether environmental pressures on a nation's human welfare are improving or getting worse, and a comparison of such an index across countries could reveal trouble spots where the international community might want to help diffuse threats to human welfare or lessen the inequity of environmental risks. This index could provide important environmental information; it could also be combined with other health information to create an overall health index of use as an indicator of sustainable development.

> ***"Further discussion is needed to establish a consensus on how to measure social equity in environmental exposures."***

IX. APPROACHES TO SUSTAINABLE DEVELOPMENT INDICATORS

This report spells out an approach to structure environmental pressure indicators into four highly aggregated indices. The working assumption is that a similar approach could be taken to construct state and response environmental indicators. In this chapter, we move beyond environmental indicators to consider in a preliminary way integrated frameworks and indicators for sustainable development.

The concept of sustainable development represents an attempt to reconcile or establish a balance among economic, social, and environmental factors. As part of efforts to give the term operational meaning, many proposals for indicators of sustainable development have emerged since the 1992 Earth Summit on environment and development. Those involved generally agree that a suitable overall framework must link the environment to economic and human development, but beyond that opinion diverges—witness the following sampling of information tools being considered or proposed.

One approach is simply to extend the pressure-state-response framework used for environmental indicators into economic and social realms. That approach is reflected in a preliminary list of sustainable development indicators prepared jointly by the staff of the U.N. Commission on Sustainable Development and the U.N. Statistical Office (UNSTAT) and in a similar list contained in a forthcoming World Bank publication, *Monitoring Environmental Progress.* Such lists are typically presented as a large matrix of indicators, with columns representing pressure, state, and response and rows clustered by *Agenda 21* topics or lists of issues (including those discussed in this report). In an environmental context, the pressure-state-response framework highlights the causal link between environmental pressures and the degradation of the environment, thus connecting to a key environmental goal of sustainable development (managing pressures to maintain environmental quality). In economic and social contexts, the framework is taxonomic rather than causal—there is no inherent connection between pressure and state indicators. How existing economic and social indicators fit into such a framework also appears to be somewhat arbitrary.

A second approach, proposed by Peter Bartelmus of UNSTAT, consists of pairing sustainability policy issues (represented by clusters of *Agenda 21* topics) with data-collection and statistical validity issues, as represented by indicators selected from the Framework for the Development of Environmental Statistics and other standard statistical series.[22] This approach yields a large set of indicators that can be undergirded by generally reliable data, but reflects the point of view of data providers rather than users and, more important, does not address some important issues for which solid data are not yet available (such as life-support issues).

A third approach, proposed by Albert Adriaanse, of the Dutch Ministry of Housing, Physical Planning, and the Environment (and a co-author of this report), follows the conceptual approach used here to develop aggregated environmental indicators. Indicators in economic and social domains, as in the environment, would be structured by a few key determinants (or indices) that reflect the primary policy focus in each domain.[23] For environmental policy, the proposed determinants are resource use, pollution releases, and ecosystem risk; for economic policy, resource use, productivity, poverty and equity, and investment; and for social policy, education, health, and the status of women. Although the environmental determinants of this approach arise out of a model of human interactions with the environment, the proposed economic and social determinants are more ad hoc; ideally, the choice of those determinants should arise out of an international discussion of users' needs.

Just such an approach is proposed by members of the U.S. Interagency Working Group on

Sustainable Development Indicators. This team is trying to expand the causal chain of the pressure-state-response framework and apply it equally to environmental, social, and economic variables.[24] In their approach, the links in this chain are natural events and human activities; causes of change (both positive and negative); states of economic assets, natural and environmental resources, and social capital; measures of human well-being; and responses. The U.S. group is also calling for the development of new indicators of social capital.

Another approach, proposed by Edgar E. Gutierrez-Espeleta of the University of Costa Rica, a consultant to the Earth Council, bases a framework for sustainable development indicators on concepts or attributes of agro-ecosystems: productivity, equity, resilience, and stability.[25] Environmental, economic, and social indicators already in use represent these attributes at a national level, and they are aggregated first under each attribute and then into a single Approximated Sustainability Index. But the indicators of each attribute appear to be assigned somewhat arbitrarily and the attributes themselves may overlap. (Resilience and stability, for instance, are similar.) The approach has been applied in an illustrative way to calculate an overall index for Costa Rica over a period of years.

Other approaches to measuring sustainability based on natural resource accounting or on alternative economic concepts—such as sustainable economic welfare—have also been proposed and illustrated in country-specific applications.[26] One of the most explicit is that proposed by David Pearce and his colleagues at University College-London, which builds on his definitions of "weak" and "strong" sustainability. Pearce suggests focusing on savings rates and argues that sustainability in the weak sense means that the value of savings must at least equal the depreciation of manufactured capital less the depletion of natural capital, so that society's total capital does not decline.[27] For strong sustainability, an additional constraint applies: the natural capital stocks on which the life-support system depends must also not decline. More recent work at University College-London and at the World Bank focuses on measures of total wealth as well as net savings.[28, 29] Such economic approaches have many useful applications. But, because they depend on monetary valuation and the price system, they can't easily incorporate aspects of environmental or social sustainability that have no price. Thus while such approaches provide an important method of creating indicators (as is illustrated in Chapter VI of this report), they may not be broad enough to serve as an overall framework for monitoring and guiding sustainable development.

Indicators are not an end in themselves. Rather, they are tools that, used with wisdom and restraint, can build support for needed change.

The proposals discussed here exemplify, but by no means exhaust, the range of options for creating integrated frameworks for sustainable development indicators. Each has distinct advantages and innovative features, but it seems premature to endorse any particular one. Indeed, the proper framework for economic and social (as well as environmental) indicators of sustainable development belongs high on the international research agenda. Such research offers an important opportunity to free society from world views that have outlived their utility and, hence, to rethink whether existing social, economic, and environmental indicators continue adequate for the future.

Of course, indicators are not an end in themselves. Rather, they are tools that, used with wisdom and restraint, can build support for needed changes and guide the actions of governments, international organizations, the private sector, NGOs and other major groups toward sustainability.

X. IMPLICATIONS FOR ACTION

Although this report has focused on a core list of environmental issues, these are far from the only environmental concerns. Nor will they have equal importance in all regions or over all time.

For this reason, environmental indicators —and sustainable development indicators as well—must be viewed flexibly and need to be subject to frequent reconsideration as conditions change, new issues arise, and responses to some problems begin to work.

IMPLICATIONS FOR DATA COLLECTION AND STATISTICAL REPORTING

The four highly aggregated indices proposed in this report rest on a core set of more than 20 environmental indicators that are, in turn, based on a significantly larger field of primary data and analytical procedures. Thus, this or any set of indicators chosen to guide national policy-making and international reporting also has implications for the rest of the information pyramid: they establish implicit priorities for environmental monitoring and thus structure data collection and analysis. Many existing statistical series—as assembled in the pre-UNCED Framework for the Development of Environmental Statistics, for example—focus heavily on the environmental problems common in industrial countries, such as pollution, and slight those most pressing in developing countries, such as environmental impacts on health and the depletion of renewable resources. Nor do they provide an appropriate "geo-referenced" or location-specific information base for such issues as biodiversity and land use.

We do not believe that nations should focus solely on the data that support the indicators outlined in this report. Certainly each nation will have its own priorities for data collection and analysis, reflecting local needs for resource management, environmental regulation, etc. Yet, both international organizations and individual nations should note the data needs that these indicators (or others that become widely accepted) imply and, where possible, incorporate these data and analytical procedures into their standard environmental monitoring and data-reporting efforts. The development of such a common database would itself be a significant step toward improving shared knowledge of the environmental pressures on the planet and the effectiveness of current policies in counteracting them. The broader awareness of environmental pressures that would result from such a common data-collection, analysis, and reporting effort (and from similar efforts on economic and social indicators) itself is an essential precondition for sustainable development.

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Each nation will have its own priorities for data collection and analysis, reflecting local needs for resource management and environmental regulation.

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INVOLVING USERS

Indicators play a key role in the policy process by reducing uncertainty in decisionmaking or otherwise facilitating better decisions. But indicators can play such a role only if decisionmakers consider them useful and use them. In the end, only users know what information they need—the bedrock principle for those who structure the data collection, analysis, interpretation and aggregation that results in indicators.

A complicating matter is the need for convergence. The users of the indicators discussed in this report are national and international decisionmakers, an audience that spans many interests and needs. But if each country uses different indicators or different methodologies, international agencies can't plan effectively and opportunities for countries to cooperate to solve global or continent-wide environmental issues may be missed. Thus, we plead strongly for international discussions to bring about a consensus on which indicators to develop first and which methodologies to use. Obviously, convergence can be facilitated by the use of electronic networks and other modern information technologies and techniques.

REPORTING TO THE PUBLIC

The format in which indicators are reported can significantly add to or detract from effective communication. Graphical presentations can help users visualize key information, and so can short textual explanations. Conversely, long or overly technical presentations may irritate or exclude both decisionmakers and the larger public.

One model format for reporting is used by the Canadian government for environmental indicators. Each edition of this 4-page nontechnical bulletin treats a given environmental issue. Each includes pressure, state, and response indicators in graphical form, together with explanatory text. *(See Appendix 2.)* Technical details are published in an accompanying bulletin. Similar short bulletins have also been used by the Dutch government and are being considered by the U.S. Environmental Protection Agency.

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APPENDIX I.

Valuation Methods in Natural Resource Accounting

Two primary means of market valuation are used in natural resource accounting studies: the net-rent method and the user-cost method. Strictly speaking, both methods are applicable only to the use of non-renewable resources, but have been applied to renewable resources on the assumption that these resources are being used up or mined as if they were non-renewable. For the net-rent method, the unit value (or net-rent per unit) is calculated by subtracting from the unit price all unit costs necessary for the resource owner to obtain that price, including the cost of capital (1)(2). The total depreciation estimate is equal to the quantity change in the resource times the net-rent. The user-cost method determines how much the user of a non-renewable resource would need to invest to obtain a constant and perpetual flow of income (3).

The user-cost method is theoretically correct if the price of the resource is constant over a known period until the resource is completely exhausted and if the interest rate is known in advance. The net-rent method is theoretically correct if the net-rent is rising at the rate of interest, a phenomenon that is consistent with basic theory but inconsistent with historical trends of most natural resource prices. While neither method is entirely satisfactory, the comparatively simple net-rent method has been applied in more case studies than the user-cost method. In studies where both values were calculated, the depreciation estimate based on the net-rent method is used here to maximize comparability across countries.

The non-market valuation of resources is necessary when the resource to be evaluated does not have a market price. Soils, fisheries, and the environmental services provided by ecosystems are examples of such resources. Various methodologies can be used to value resources when a price cannot be observed (4). Which works best in each instance depends upon the resource involved, the source of the physical changes, and the data available.

Country Notes

Alaska, United States. Oil is the only natural resource considered in the analysis. In the original study, additions to the asset base were not identified separately (5). For years in which major increases occurred (1961, 1969, and 1978), depletion of the stock was estimated assuming that the ratio of depletion to value-added in those years was the same as in the next year. Resource depreciation is estimated using the net-rent method. The relatively low unit values reflect high development costs.

Alberta, Canada. Resource-depreciation estimates are made for forests (6), oil and natural gas (7), and soils (8). Resource-depreciation estimates for oil and natural gas include only extraction; new finds are not counted. Forest depreciation (or appreciation) corresponds to anthropogenic changes in volume, so fires are excluded but managed growth is included. To assign value to forests, the net-rent method is used. The estimated value of soil erosion is so small that it does not affect the indicators.

Australia. Indicators are derived from very rough estimates of resource depreciation (9). Depreciation estimates include soil erosion, salinity, habitat loss, and changes in the value of mineral stocks. In estimates of erosion, the assumption is that on-site productivity losses total $5,000 per farm and that off-site costs equal 50 percent of on-site losses. To capture the positive relationship between total rainfall and erosion, all losses are weighted by the inverse of the nation's wheat yield. Damages due to salinity are taken from case studies and reflect current costs imposed upon families and agriculture.

Habitat loss is valued at $1,000 per hectare, and the total loss of native forests is roughly estimated at 230 thousand hectares per year. Mineral depreciation is valued using the net-price method. Mineral accounts include both new finds and revaluations, which is inconsistent with the SEEA and, therefore, with the statistics for the other countries presented here.

Brazil. Resource depreciation covers forest and mineral resources (10). Forest resources include extractive products—latex, chestnut, babassu, palm cabbage, and carnauba—and are valued using the net-rent method. Mineral resources include oil, coal, lead, chromium, iron, aluminum, gold, tin, manganese, tungsten, calcareous rock, and white clay. Mineral values used here are taken from the user-cost method. National Accounts (GDP and GFCF) data are taken from World Tables (11) in 1987 cruzados and converted first to 1987 dollars and then to 1980 dollars using the GDP deflator.

China. Depreciation covers coal, iron, and Beijing's groundwater resources (12). Volume withdrawals are valued using net-rent method. Groundwater resources are valued using an adaptation of the net-price method in which an estimate of the price that would yield demand at a target level is used rather than prevailing price per cubic meter. The single year price of $0.29 per cubic meter is then applied to all years for which physical estimates are available. National accounts data are taken from U.N. National Income Accounts. Sector level values of Gross Domestic Product are not available, so the alternative, Net Material Product, is used.

Costa Rica. Resource depreciation includes loss of timber plus the resource loss attributable to the conversion of land, fisheries depletion, and soil erosion (13). Standing timber is valued using the net-rent method, and the loss due to land conversion is valued as though under a sustainable forest management plan. Fisheries depreciation for the Gulf of Nicoya is valued by the decline in asset value of the fishery attributable to the expansion of the fishing fleet. Soil-erosion losses are valued using the replacement cost method. Gross fixed capital formation data are taken from the UN *National Accounts Statistics* from a variety of years. When data is available only in constant 1984 colones, it is converted to 1966 colones using the implicit deflator for capital formation.

Indonesia. Oil, forest, and soil depreciation are included (2)(14). For oil and forests, the value of stock changes is calculated using the net-rent method. Oil-depreciation values used here exclude new finds, which are included in the original study. Values for forest depreciation do not take losses due to fire into account. The estimates of depreciation for 1985-1987 include only oil depreciation. The on-site cost of soil erosion is calculated using the value of the decline in soil productivity for the island of Java. Data on gross fixed capital formation data are taken from the UN *National Accounts Statistics* from a variety of years. Gross fixed capital formation for 1970-1983 includes changes in stocks and, for 1983-1987, are converted to 1973 rupiah using the average deflator for capital from 1980 to 1983.

Mexico. Resource depreciation includes oil, timber, transfers of land to agriculture, soil erosion, the degradation of land by solid wastes, net groundwater extraction, water pollution, and air pollution (15). Valuation of oil and timber is based on the net-rent method. Land transfers from forest to other uses are valued by considering the net-value added by forestry. All other sources of degradation are valued according to the cost of avoiding such damage.

Nepal. Depreciation includes the loss of forests and soils (16). Forest values reflect both timber and fuelwood. Valuation is based upon the net-rent method, though the estimates are preliminary and the methodology is sketchy. Soil erosion is valued taking into account both soil productivity loss and the replacement cost. Total fertilizer expenditures are used as a proxy for the replacement cost. Although the methodology is not presented in detail, this appears to be a double counting of the value of soil-depreciation losses. Data on gross fixed capital formation data are taken from the UN *National Accounts Statistics* for a variety of years. Constant GFCF values are calculated using the GDP deflator. The capital consumption allowance (depreciation of man-made capital) is calculated as the difference between GDP and NDP presented in the study.

Papua New Guinea. Resource depletion includes oil, timber losses associated with logging and transfers of land to agriculture, soil erosion, the degradation of land by solid wastes, net groundwater extraction, water pollution, and air pollution (17). Valuation of oil and timber is based on the net-rent method, and degradation issues are valued according to the cost of avoiding such damage. Gross and net products of the forest, electric, and mining sub-sectors were not available for all years, so these quantities were estimated. (The assumption is that the share of these sub-sectors in the sector product remains constant over the period.) Data on gross fixed capital formation are taken from the UN *National Accounts Statistics* for a variety of years.

Philippines (WRI Study). Resource depreciation includes timber, soil erosion, and coastal fisheries (18). Timber depreciation is valued using the net-rent. Net depreciation includes growth, reforestation, harvesting, deforestation, and logging damage. Fire damage is excluded in the current summary statistics here but is included in the original study. Soil degradation is estimated on the assumption that the replacement cost of nutrients eroded from upland crops is $50 per hectare. Fishery depreciation is estimated on the assumption that asset value declines linearly from 1970 to 1984, by which time the fishery's asset value had fallen to zero. Fishery depreciation is set equal to zero from 1984 to 1987. National Accounts data are taken from United Nations (various years). Data for 1970-1979 were converted from 1972 pesos to 1985 pesos in order to be consistent with the study using the average implicit ratio of 1985 constant values to 1972 constant values for the years 1980-1989. Data on the consumption of fixed capital were converted to constant pesos using the GFCF deflator.

Philippines (NRAP Study). Depreciation estimates are taken from Phase I of the Philippine Natural Resource Accounting Project (19)(20)(21)(22)(23). Phase II estimates would add a number of sources of resource depreciation and degradation, but are for only single year values, so these values are not considered here. Depreciation estimates are made for forest resources (dipterocarp, pine plantation, and mangrove) and rattan for the period 1970-1989 using the net-rent method. Data on national accounts are taken from United Nations (various years).

Thailand. Only the depreciation of forest resources is considered (24). For the statistics here, timber depreciation is valued using the net-rent method, though in the original paper user-cost valuation is also presented. Data on gross fixed capital formation and capital consumption allowance are taken from UN *National Accounts Statistics* from a variety of years.

United Kingdom. Resource depreciation includes depletion of oil, coal, and natural gas for all years and includes estimates of the value of the net change in forest, and of the degradation of land, water, and unspecified "other" resources only for 1990 (25). The depreciation of subsoil assets is calculated using the user-cost method. Other sources of environmental degradation are valued based on the cost of preventing the degradation. Data on standard national accounts come from the official national accounts of the United Kingdom.

United States (G&M Study). Resource depreciation includes the net change in timber resources, plus oil and mineral depletion, as well as the degradation of groundwater and air quality, and the environmental costs of solid wastes (26). Timber and mineral resources are valued using the net-rent method. Air pollution and water pollution are valued based on the estimated cost of reducing the flow of pollutants to zero.

United States (B.E.A. Study). Depreciation includes that of subsoil assets for the entire period (27)(28). Depreciation and degradation of timber stocks, vineyards, cattle and calves, and soil are estimated for 1987 only. Stock changes are valued here using the net-price method, though other methods are explored. Current value estimates were used to generate the summary statistics. Data on national accounts are taken from World Bank and United Nations sources. The data needed to calculate the value added by agriculture for the years 1987-1990 were unavailable.

Zimbabwe. Depreciation estimates are for forests (based on their value as sources of fuelwood) and for soil erosion (29). The valuation of forest depreciation is conducted using the net-rent method. Soil erosion is valued using estimates of the decline in the soil's productive capacity. Depreciation of man-made capital includes only that in the agricultural sector and that is calculated by the authors.

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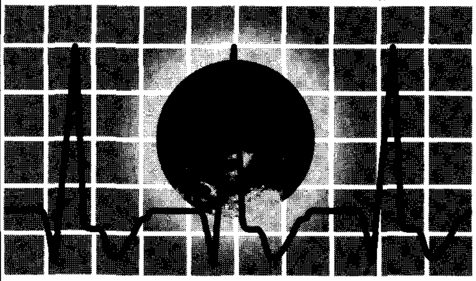
APPENDIX II. ENVIRONMENTAL INDICATOR REPORTING FORMATS

Following are indicator bulletins or reporting formats from Canada and the Netherlands.



ENVIRONMENTAL INDICATOR BULLETIN

STRATOSPHERIC OZONE DEPLETION

Issue Context

Ozone is a naturally occurring gas that is found in trace quantities throughout the atmosphere but is most abundant in the stratosphere, at an altitude of 20–40 km, where it forms the stratospheric ozone layer. This layer of ozone varies naturally in density. It shields the earth's surface from extreme intensities of ultraviolet radiation and influences the heating and cooling of the Earth and its atmosphere.

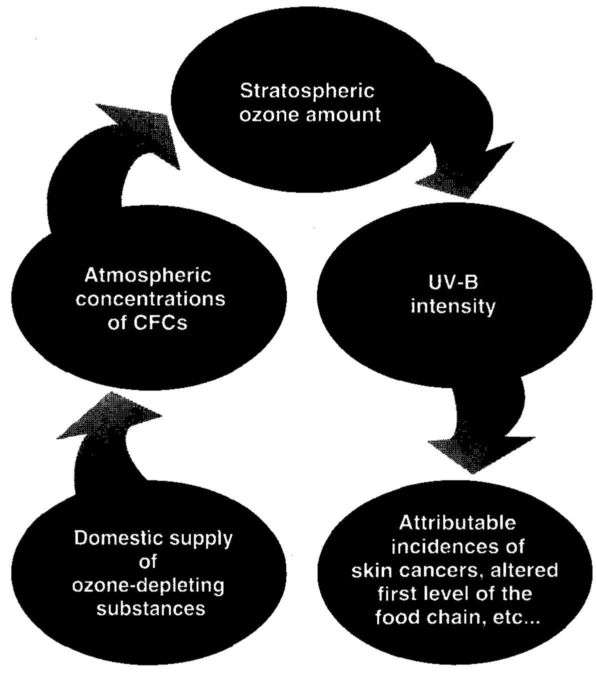
Depletion of the stratospheric ozone layer has been linked to the action of a number of manufactured chlorine and bromine compounds. Their long lifetimes allow them to penetrate the stratosphere, where they eventually break down, releasing ozone-depleting chlorine and bromine. Investigations of the seasonal antarctic ozone "holes" and other studies have confirmed the involvement of these chemicals in stratospheric ozone destruction.

As stratospheric ozone diminishes, increased intensities of ultraviolet radiation — particularly the more energetic UV-B wavelengths — are expected at the Earth's surface. Excessive exposure to UV-B radiation is known to increase the incidence of sunburns, skin cancer, cataracts, and damage to the immune system in humans, to reduce the yields of crops, and to cause disruption of marine food chains. Reduction of stratospheric ozone could also contribute to changes in world climate patterns.

The Montreal Protocol of 1987 and subsequent amendments have set timetables for phasing out the production of the major ozone-depleting substances. Eighty-six countries, including Canada and all major producers of ozone-depleting substances, had ratified the Montreal Protocol as of September 1992.

The issue of stratospheric ozone depletion can be represented by a sequence of indicators, beginning with the production of ozone-depleting chemicals and ending with the effects of increased levels of ultraviolet-B radiation.

STRATOSPHERIC OZONE DEPLETION INDICATORS



The indicators in this bulletin reflect the first three stages of this cycle.

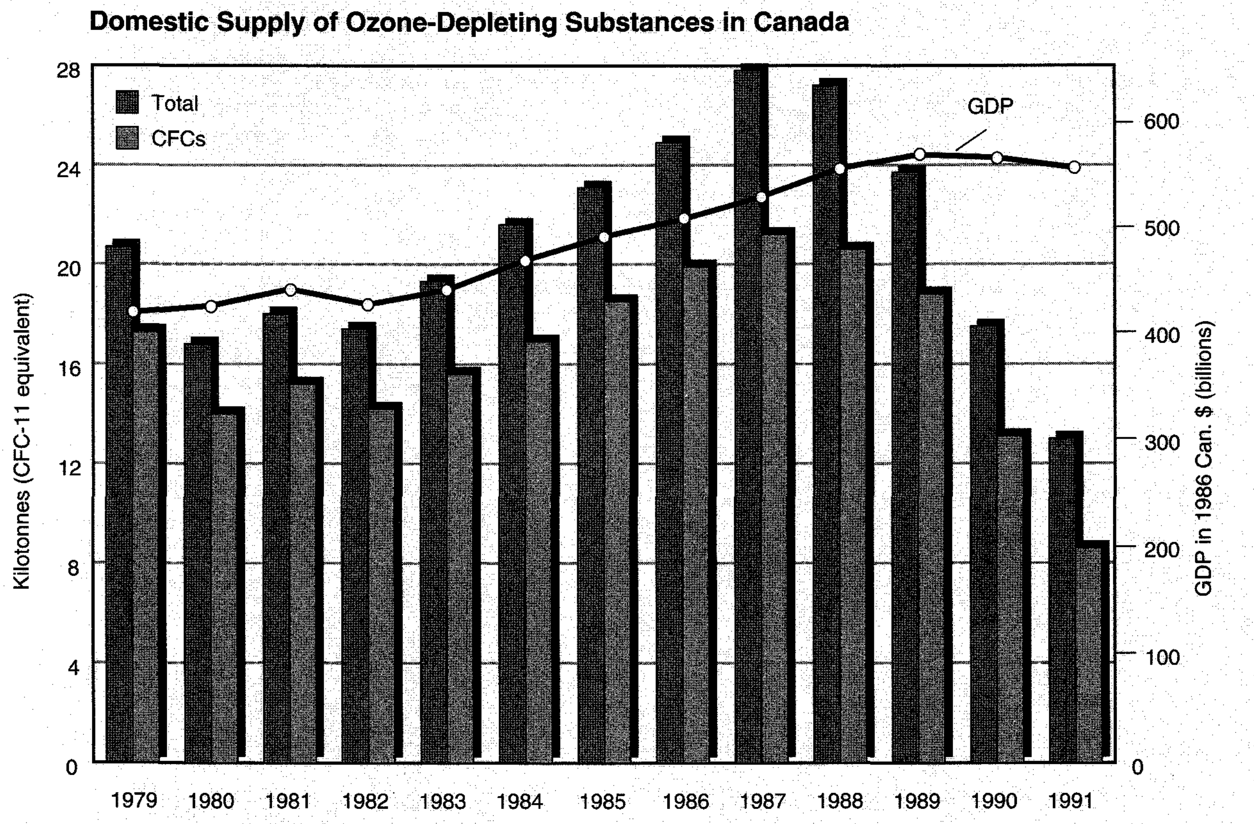
Indicator: *Canadian domestic supply of ozone-depleting substances.*

Indicator: *Global atmospheric concentrations of CFC-11 and CFC-12.*

Indicator: *Stratospheric ozone levels over Canada.*

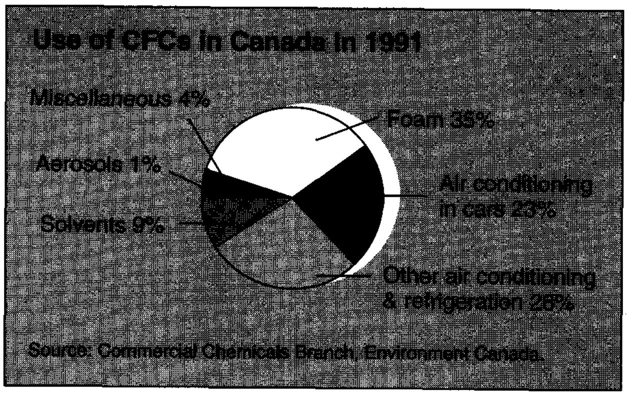
Further indicators may be introduced at a later date to measure (1) *trends in the intensity of UV-B reaching the earth's surface; and* (2) *effects of increasing UV-B intensities on human health and on food production in Canada,* once statistically reliable data bases have been established.

INDICATOR: CANADIAN DOMESTIC SUPPLY OF OZONE-DEPLETING SUBSTANCES



GDP: Gross Domestic Product
Source: Commercial Chemicals Branch, Environment Canada; Statistics Canada.

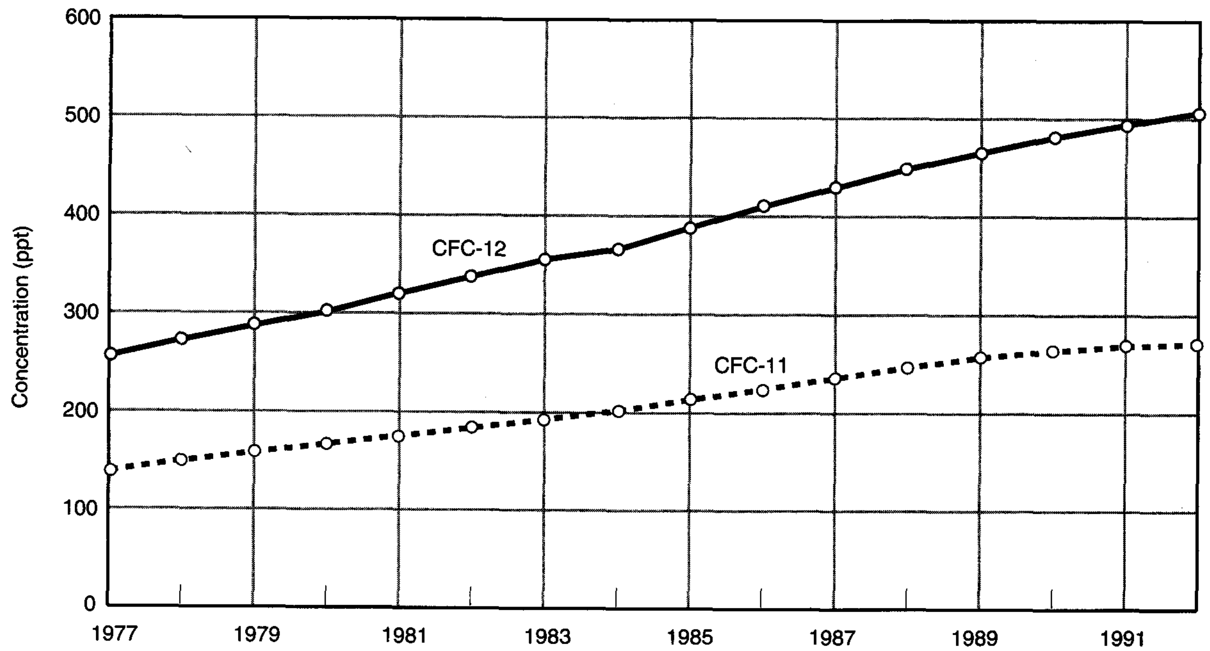
- Canadian domestic supply (production plus imports minus exports) of ozone-depleting substances has decreased by 53%, from a peak of 27.8 kilotonnes in 1987 to 13 kilotonnes in 1991.
- The trend in domestic supply of ozone-depleting substances tends to parallel an increase in economic activity, as represented by the Canadian GDP, up to 1987 but declines in relative terms thereafter.
- Individual ozone-depleting substances vary considerably in their capacity to destroy ozone. To reflect the combined destruction capacity of all ozone-depleting substances more accurately, the total for each chemical has been weighted in proportion to its ozone-depleting potential relative to CFC-11.
- The ozone-depleting substances in this indicator include chlorofluorocarbons, halons, methyl chloroform, carbon tetrachloride and hydrochlorofluorocarbons, but not methyl bromide for which data are unavailable.
- Canada accounted for just under 2% of the world's supply of CFCs and halons in 1986.



- Global supply of CFCs and halons declined by 31% from an estimated 1260 kilotonnes to 870 kilotonnes between 1986 and 1990.
- At the end of 1990, countries that had ratified the Montreal Protocol accounted for about 93% of world supply of CFCs and halons. Other countries, including India and China, have since ratified the protocol.
- CFCs are the most widely used and abundant of ozone-depleting substances.

INDICATOR: GLOBAL ATMOSPHERIC CONCENTRATIONS OF CFC-11 AND CFC-12

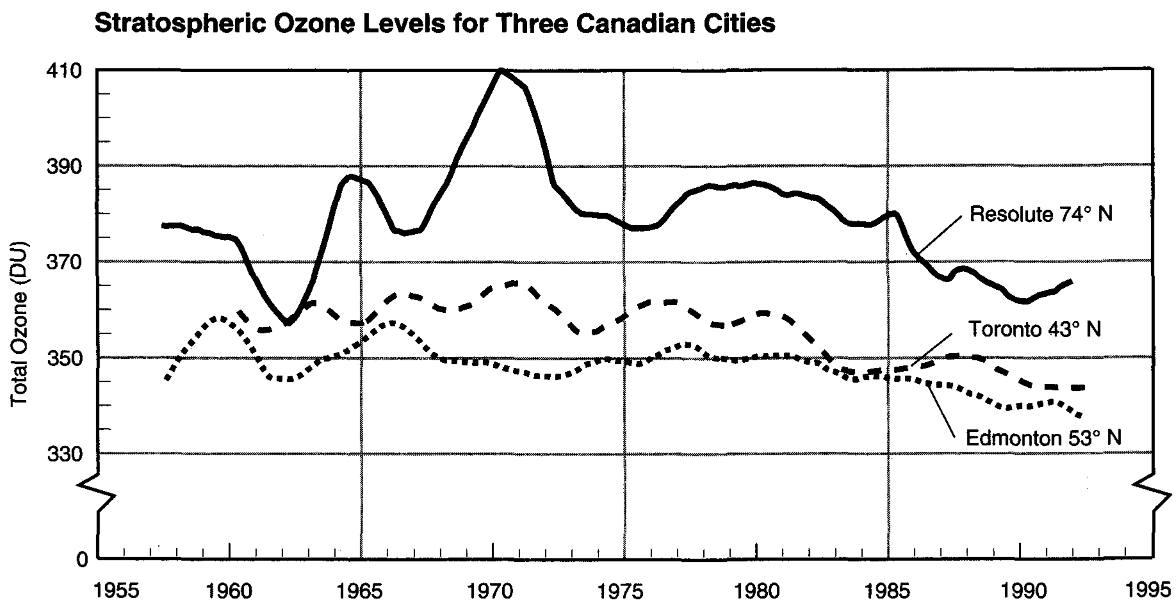
Global Atmospheric Concentrations of CFC-11 and CFC-12



ppt = parts per trillion
Source: Elkins, et al., NOAA, Boulder, Colorado, U.S.A.

- This indicator tracks the magnitude and rate of change of the atmospheric reservoir of the most abundant ozone-depleting substances. Because of the long lifetimes of these chemicals and the quantities still contained in cooling systems and rigid foams, with the potential to escape, these chemicals will persist in the atmosphere for decades. There is therefore concern that CFCs will continue to cause stratospheric ozone depletion long after their production has ceased.
- It is technically difficult to report on all CFCs in the atmosphere. However, CFCs -11 and -12 account for half of the ozone-depleting chlorine in the atmosphere.
- Global atmospheric concentrations of CFC-11 and CFC-12 have increased steadily since measurements began in 1977. However the rate at which CFC-11 has been increasing has slowed since 1989.

INDICATOR: STRATOSPHERIC OZONE LEVELS OVER CANADA



DU = Dobson Unit
Source: Atmospheric Environment Service, Environment Canada

- Stratospheric ozone levels over Toronto and Edmonton have declined by about 4% since the late 1970's. These observations are consistent with results from other mid-latitude stations in the northern hemisphere. The trend is less clear for Resolute.
- The observed decline over Canada is still considered to be within the range of natural ozone fluctuations and has not yet been conclusively attributed to the effects of manufactured ozone-depleting substances.
- The data have been statistically smoothed over a two-year period to adjust for natural fluctuations due to the biennial oscillation of stratospheric wind patterns. Other natural factors affecting ozone levels include seasonal changes in solar radiation, the 11-year sunspot cycle, the sporadic El Niño Southern Oscillation every 3–5 years, and volcanic eruptions.
- The indicator measures total ozone, which includes tropospheric (the air between the earth's surface and the stratosphere) as well as stratospheric ozone. Stratospheric ozone accounts, on average, for about 90% of the total ozone column. Increases in tropospheric ozone as a result of urban air pollution may partially mask a decline in stratospheric concentrations.

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Statistics Canada.

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INFORMATIEBLAD KLIMAATVERANDERING

Dit informatieblad gaat in op een onderwerp uit het NMP 2 aangevuld met de inzichten uit het Milieuprogramma 1995 - 1998. Meer informatie over dit onderwerp kunt u verkrijgen bij het Bureau Persoonlijke Voorlichting van het Ministerie van VROM, telefoonnummer 070 - 339 50 50.

Er zijn informatiebladen van de milieuthema's klimaatverandering, verzuring, vermesting, verspreiding, verwijdering, verstoring, verdroging en verspilling. Ook zijn er informatiebladen van de doelgroepen van het milieubeleid landbouw, bouw, industrie, raffinaderijen, energiebedrijven, verkeer en vervoer, consumenten en afvalbedrijven.

BESCHRIJVING THEMA

probleem
- broeikaseffect
- afbraak ozonlaag

mogelijke effecten
- stijging gemiddelde temperatuur
- verschuiving klimaatzones
- zeespiegelstijging
- huidkanker, staar, verminderde weerstand

oorzaken
- verbruik fossiele brandstoffen, onder meer in het verkeer (CO_2, CO, NO_x, N_2O)
- ontbossing (CO_2)
- energiewinning en -transport (CH_4)
- voedselproduktie (CH_4)
- storten van afval (CH_4)
- industriële produktie (CFK's en halonen)
- verbruik kunstmest (N_2O)

relevante stoffen
- koolstofdioxide (CO_2)
- methaan (CH_4)
- distikstofoxide (N_2O)
- chloorfluorkoolwaterstoffen (CFK's)
- halonen
- stikstofoxiden (NO_x)
- koolstofmonoxide (CO)
- ozon (O_3) (gevormd door NO_x, CO_2, CH_4)

belangrijkste sectoren
- industrie, energiebedrijven, verkeer en vervoer, huishoudens

ALGEMENE AANPAK NMP 1

- broeikaseffect
  - . energiebesparing (ook voor verkeer en vervoer)
  - . stromingsenergie
  - . verschuiving brandstofinzet (van kolen naar aardgas)
  - . gebruik afvalwarmte (WKK, stadsverwarming)

- *aantasting ozonlaag*
  - . snelle afbouw gebruik ozonaantastende stoffen
  - . vernietiging CFK's, halonen

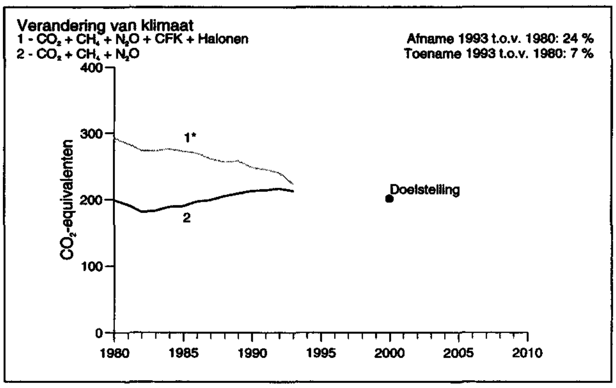
Doelstellingen 2000

- broeikas-effect
  - . CO_2: 3-5 % emissie-reductie t.o.v. 1989/1990
  - . CH_4: 10 % emissie-reductie t.o.v. 1990
  - . N_2O: stabilisatie t.o.v. 1990

- aantasting ozon-laag
  - . CFK's: 100% reductie (in 1996)
  - . halonen: 100% reductie (in 1994)

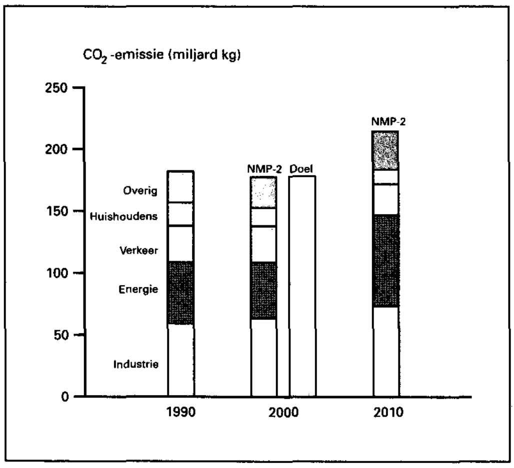
1994

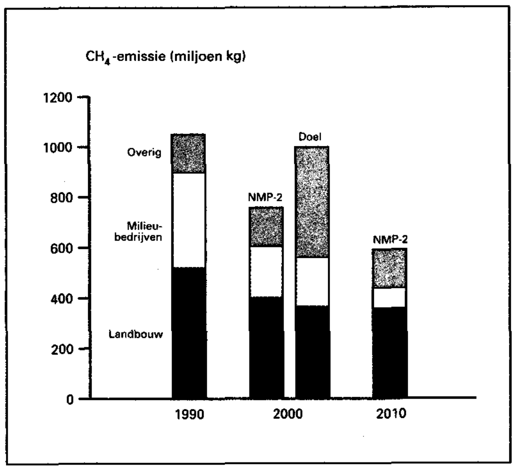
2 Ontwikkelingen 'broeikas-effect'

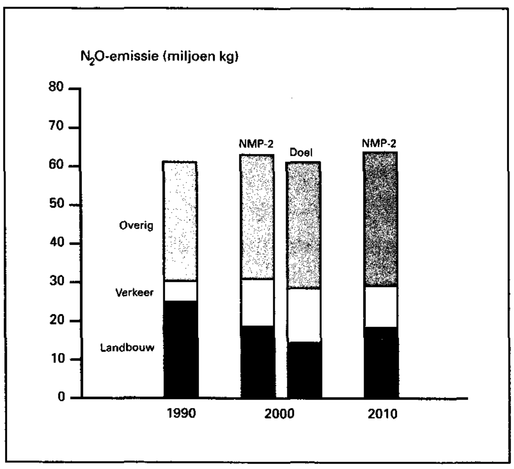


*) *Bij lijn 1 zijn de indirecte effecten van CFK's en halonen, die de broeikaswerking aanzienlijk afzwakken, weggelaten; de bijdrage van CFK's en halonen is dus uitsluitend gebaseerd op de (sterke) directe broeikaswerking, hetgeen als theoretisch maximum kan worden beschouwd.*

Bijdragen sectoren

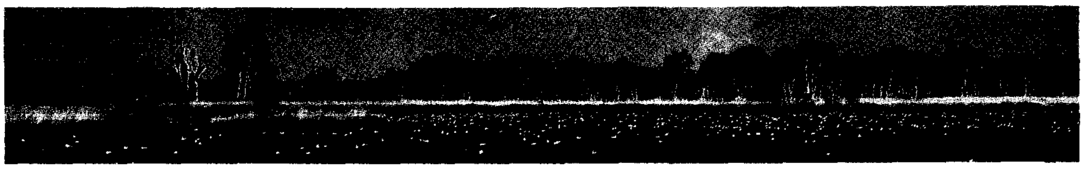




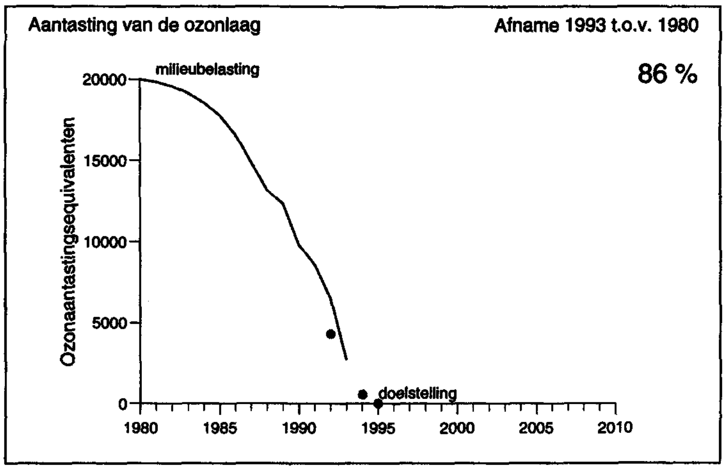


Conclusie

- zonder aanvullend beleid zal in 2000 nog 15 Mton CO_2 teveel worden uitgestoten om de doelstelling van -3% te kunnen halen
- de doelstelling voor CH_4 en N_2O zal worden gehaald



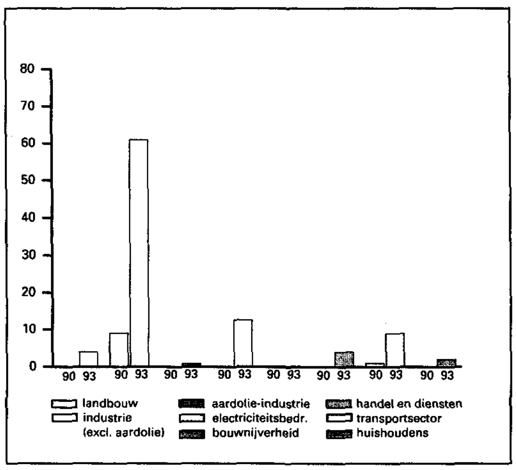
Ontwikkelingen 'aantasting ozonlaag'



Conclusie

- realisatie doelstellingen CFK's en halonen op schema

Ontwikkeling milieulasten thema Klimaatverandering (mln gulden/jaar)



ALGEMENE AANPAK NMP 2

Uitgangspunten
- doelstellingen blijven gehandhaafd; 3% reductie wordt met maatregelen ingevuld
- beslissing over 5 % reductiedoelstelling in 1995
- blijvende erkenning klimaatprobleem
- internationale aanpak (uitvoering Klimaatverdrag VN)
- CO_2-uitstoot mag na 2000 in principe niet verder toenemen (EG stabilisatiedoelstelling)
- voortzetting CFK-aktieprogramma

Onzekerheden
- ontwikkeling van de economische groei
- ontwikkeling energieprijzen

Pregnante maatregelen
- voorkeur energieheffing in EG, voorbereiding invoering nationaal of in EG-verband, beslissing in 1994
- verdere energiebesparing in meerdere sectoren, onder meer door meerjarenafspraken
- uitvoering Milieu-actieprogramma 2(MAP 2) (begin 1994 door elektriciteitsdistributiesector vast te stellen), CO_2-convenant (SEP) en Milieuplan Industrie (Gasunie)
- inzet Wet Milieubeheer (vergunningen, AMvB's) ter ondersteuning meerjarenafspraken, etc.
- verkeersmaatregelen, waaronder rekeningrijden en Europese regelgeving CO_2-emissiereductie
- CO_2-certificaten in verband met bosaanplant
- intensiveren beleid N_2O en HCFK's

Conclusie
- indien rekening wordt gehouden met EG-heffing en mogelijke meevallers wordt 3 % reductie van CO_2 in 2000 gerealiseerd

Overzicht uitvoering

Wat is in uitvoering:
- Nota klimaatverandering
- CFK-actieprogramma
- Nota Energiebesparing
- MAP 1

Wat komt in uitvoering:
- CO_2-convenant SEP
- MAP 2
- 2e fase nationaal onderzoeksprogramma mondiale luchtverontreiniging en klimaatverandering
- proefprojecten Joint Implementation
- Vervolgnota energiebesparing
- Vervolgnota klimaatverandering
- Aktieprogramma technologieontwikkeling voor de lange termijn
- demonstratie-project energie-extensivering huishoudens
- maatregelen t.a.v. wegverkeer
- bijdragen aan tot stand brengen EG-regelgeving CO_2-emissies wegvoertuigen
- intensivering energiewinning afval
- CO_2-certificaten

Extra aandacht nodig voor:
- achtergronddocument HFK's en N_2O (actie nr. 51)
- EG-klimaatbeleid (actie nr. 81)
- acceptatie 'Joint Implementation' internationaal
- steun ontwikkelingslanden
- ontwikkeling technologie
- Klimaatkaderverdrag

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