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MEASURING SUSTAINABLE DEVELOPMENT: REVIEW OF CURRENT PRACTICE

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MEASURING SUSTAINABLE DEVELOPMENT: REVIEW OF CURRENT PRACTICE

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FOREWORD

This study was commissioned by Industry Canada as part of its preparations to meet the requirements of new Canadian legislation. These include the need to develop a sustainable development strategy for Industry Canada and to measure progress in achieving the strategy. Reports on both topics must be submitted to Parliament, and may be commented on by the Commissioner of the Environment and Sustainable Development, whose office forms part of the Office of the Auditor General of Canada.

The study's primary goal is to review the leading approaches to measuring sustainable development. The examples used are chosen from measurement projects currently under way, in order to highlight some practical solutions for measuring sustainable development. Therefore, they cover a variety of jurisdictional levels, and the private and public sectors.

This report builds on previous and ongoing work by the Measurement and Indicators Program of the Institute of Sustainable Development (IISD). The authors would like to thank Lee Gill, Tereasa Chudy, Philip Fleming, Victoria Rowbotham, Someshwar Rao and Louis Beauséjour, all of Industry Canada, for helpful guidance and comments. An anonymous referee also provided helpful comments. At IISD, thanks are due to Julie Wagemakers for comments and to Valentina Kaltchev and Shannon Brown for administrative support. Any errors are the responsibility of the authors.

EXECUTIVE SUMMARY

This year, 1997, marks the 10th anniversary of the publication of the report of the World Commission on Environment and Development (WCED, 1987) and the fifth anniversary of the 1992 UN Conference on Environment and Development. It provides the last chance for major policy corrections before the new millennium. A review and an inventory of accomplishments in sustainable development are necessary preconditions for any decisions to be made.

How does one measure progress toward sustainable development? The question is simple and its importance is clear, but easy answers do not exist. This paper describes a selection of measurement approaches currently in use, and highlights aspects of particular interest to those designing their own measurement systems.

The first two chapters review the standard concepts of sustainable development and measurement, including indicators as measurement tools: the most common definitions and the basic concepts of sustainable development in Chapter 1 and measurement as an important tool for assessing progress toward sustainable development in Chapter 2. The terms "indicator" and "index," and their functions in the measurement process are also defined.

The third chapter offers practical examples of ongoing measurement work. It includes a worldwide survey of measurement projects and applied indicator sets. The examples represent the major trends of contemporary indicator work. Each example is followed by a brief analysis of its advantages and limitations, and a summary of key points for practitioners. The survey ranges from international cases through national and sub-national projects to local authorities and corporate examples. The details of the indicator sets they use are presented in Appendix A.

At the international level, work under the auspices of the United Nations Commission for Sustainable Development (UN CSD) is reviewed first. Trial implementations are under way in several countries using a set of 140 indicators developed by the UN CSD. The World Bank is taking a quite different approach, evolving a new conceptual model called the four capitals approach, which will require the development of new statistics to measure some components. The third international approach involves the correction of national accounts data that now focus only on economic issues, to incorporate sustainable development concepts. The UN Division of Statistics and several national statistical offices (including Statistics Canada) are leading this effort.

At the national level, Canada has two approaches that are reviewed in this report. The first is Environment Canada's ongoing indicator work, and the second is the linked human and ecosystem well-being approach of the National Round Table on the Environment and the Economy. The Netherlands' system, which is based on that country's National Environmental Policy Plan, is also reviewed along with work under way at the U.S. President's Council on Sustainable Development. All these national approaches try to focus attention on key national and global issues, but also link them back to national-level activities and policies.

Many of the same issues arise at the sub-national level where the exercises under way tend to be oriented toward local issues and grass-roots consultations while still, of course, relating to larger global issues. Corporate indicator work tends to focus on environmental issues, with some steps being taken to integrate initial indicators with financial issues. Little work has taken place that truly reflects the three components of sustainable development.

While the third chapter is a practical survey of existing projects, the fourth chapter offers a conceptual guide. It orients the reader among the various frameworks and models that define the purpose, focus and scope of the practical cases. It also highlights methodological problems to be solved. Finally, it briefly summarizes the present achievements and existing limitations of measurement programs.

The fifth chapter ties measurement to the decision-making process. It clarifies the role of measurement in an integrated management system and analyzes the processes in which indicators are selected and measurement is implemented. Finally, the sixth chapter provides practical guidelines for assessing progress toward sustainable development.

CHAPTER 1: SUSTAINABLE DEVELOPMENT: CONCEPTS AND DEFINITIONS

> The objective of sustainable development and the integrated nature of the global environment/development challenges pose problems for institutions, national and international, that were established on the basis of narrow preoccupations and compartmentalized concerns. Governments' general response to the speed and scale of global changes has been a reluctance to recognize sufficiently the need to change themselves. The challenges are both interdependent and integrated, requiring comprehensive approaches and popular participation.
>
> Yet most of the institutions facing those challenges tend to be independent, fragmented, working to relatively narrow mandates with closed decision processes. Those responsible for managing natural resources and protecting the environment are institutionally separated from those responsible for managing the economy. The real world of interlocked economic and ecological systems will not change; the policies and institutions concerned must (WCED, 1987, p. 9).

Management requires measurement. Managing activities and decision-making processes in order to move toward sustainable development requires new ways of assessing progress. Now as never before, communities, governments, businesses, international agencies and non-governmental organizations are concerned with establishing the means to assess and report on progress toward sustainable development. Indicators are one important tool in this process. However, current interest in this topic has yet to result in a broad consensus on a short list or a menu of indicators that could be used to replace or supplement today's dominant (mostly economic) signals of progress. One condition for such a consensus agreement involves the interpretation of the concept of sustainable development. This chapter briefly reviews some definitions of sustainable development and provides a basis for the discussion of measurement approaches that follows.

Though the Brundtland Report (WCED, 1987) offered a generally shared interpretation or contextual definition of sustainable development, relevant analyses and writings differ vastly in interpreting and defining sustainable development. The differences are so great that there is no general agreement on what should be sustained, no agreement even on what "sustain" means and, consequently, little agreement on what can or should be measured. Unfortunately, without a more-or-less shared pool of internationally acceptable definitions, it is impossible to make the comparative analysis that is a necessary condition of statements on accomplishments. The issue of definition is linked to ranking and prioritizing values and goals as well as to the policies needed to meet goals and allocate costs and benefits.

The phrase "sustainable development" and the current concept were first discussed by the World Conservation Union, also called the International Union for the Conservation of Nature and Natural Resources (IUCN), in its *World Conservation Strategy* (IUCN, 1980). That document said: "For development to be sustainable it must take account of social and ecological

factors, as well as economic ones; of the living and non-living resource base; and of the long term as well as the short term advantages and disadvantages of alternative actions" (p. 23). The *World Conservation Strategy* focused on environmental integrity, though it recognized the interrelationship between the environment, social concerns and economic activity. Only with the Brundtland Commission report *Our Common Future* (WCED, 1987) did the emphasis on the human side of sustainable development become equal to the emphasis on environmental and economic sustainability.

The most commonly used Brundtland definition ties the issue of sustainability to future generations. It is given here in full, with the qualifiers the Commission felt it necessary to add to the single sentence usually quoted.

> Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:
>
> – the concept of 'needs,' in particular the essential needs of the world's poor, to which overriding priority should be given; and
> – the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs.
>
> Thus the goals of economic and social development must be defined in terms of sustainability in all countries - developed or developing, market-oriented or centrally planned. Interpretations will vary, but must share certain general features and must flow from a consensus on the basic concept of sustainable development and on a broad strategic framework for achieving it (WCED, 1987, p. 41)

The issue of degree of emphasis on the social component of sustainable development is reflected in an ongoing debate about whether to include or exclude social indicator measurements in the definition of sustainable development. The debate arises because of a variety of conceptions of sustainable development, and it focuses especially on those components which are not commonly measured, such as the cultural and historical issues of the preservation and sustenance of cultural and community structures and values (e.g., indigenous knowledge and spiritual balance). Social indicators are considered especially controversial as they are usually embedded within the context of political and value judgments. Integrated measurement is further complicated by the different and often incompatible fields of measurement, for example, biodiversity vs. human health vs. employment vs. cultural values.

The Brundtland definition does not define a fixed state, but rather an ongoing dynamic system that can continue to evolve without self-destructing. The many different forces that act on the system must be in balance for it to be sustainable. Indicators of sustainability, then, must relate to the dynamic system in which we live. They can be aggregate measures of the stability of the whole, or more specific measures of parts of the system.

All definitions and measurements of sustainability must consider the fact that we do not really know very well how the system works. We are only discovering the environmental impacts of many of humanity's economic activities, and the interaction between growing or declining human well-being on either the environment or the economy is little understood. In other words, we know that all aspects of the system affect all others, but we do not know all the specifics of those impacts.

We also know that the system is global. Just as one actor (a company or a government department) cannot be said to be "sustainable" in and of itself, one part of the world cannot be "sustainable" if other parts are not.

The various definitions of sustainable development reflect the points made above: they often focus on the outcomes, and on maintaining system resilience rather than on the specific linkages. Indeed, it is only after the fact that a system can be said to have been "sustainable." As Costanza and Patten (1995) say, "a sustainable system is one which survives or persists." They go on to state: "But there are three additional complicating questions: (1) What system or subsystems or characteristics of the system persist? (2) For how long? (3) When do we assess whether the system or subsystem or characteristic has persisted?" (p. 193).

In this context, the above-quoted Brundtland definition is a statement about the characteristics of a sustainable human and natural system. It does not tell us how to get there.

Many other definitions are really about the specific aspects of the system that are thought to be very important in reaching sustainability. For example, the Natural Step

approach has recently been gaining prominence. It is based on "the overall physical conditions for sustainability, since nature must survive independently of how it is economically evaluated" (Robert et al., 1995, p. 31).

The Natural Step consists of four system conditions, which state goals humanity must reach if the natural sustainability of our system is to be attained. The conditions are:

- System Condition 1: Substances from the Earth's crust must not systematically increase in the ecosphere.
- System Condition 2: Substances produced by society must not systematically increase in the ecosphere.
- System Condition 3: The physical basis for the productivity and diversity of nature must not be systematically diminished.
- System Condition 4: Resources must be used fairly and efficiently with respect to meeting human needs.

Economists have approached the same set of issues, through a discussion of "weak" and "strong" sustainability. Both are based on the concept that humanity should live on the "interest" of its ecological capital, preserving the capital for future generations. The capital consists of the natural resource base (both renewable and non-renewable), biodiversity and the absorptive capacity of the ecosystem for wastes, etc. "Strong" sustainability requires that all resource levels be maintained, and not drawn down. "Weak" sustainability admits that some resources are substitutes for others (solar energy for natural gas, for example) and allows substitutions as long as the essential capacity of the ecosystem to support life is not damaged. Pezzey (1992) and Pearce et al. (1989) both discuss these concepts and other economic approaches. They also survey the different definitions of sustainable development.

Both the Natural Step approach and the discussion of weak and strong sustainability are based on an understanding that natural capital, or the ecosystems in which we live, are not replaceable by financial and human-constructed capital. The natural world must be treated as a special part of the system, not simply part of the economy for which we have not quite got the prices right. Indeed, many prefer not to use the words "natural capital," because they imply a false substitutability between the types of capital (Victor, 1991, p. 210).

Another focus is on decision-making processes. For example, according to MacNeill et al. (1991: 26-28):

> The environment and the economy must be integrated in our major institutions of decision making: Government, industry, and the home. This is perhaps the most important condition for sustainable development.
>
> Although it is possible to state the general directions in which development must proceed in order to be more rather than less sustainable…it is not yet possible to define the precise conditions for sustainability in respect to each specific development.

Once again, the statement is about system conditions, but the human decision-making system rather than the environmental system. The two are obviously related, and the emphasis of the definitions relates to author assumptions about how best to catch the attention of people and create change, rather than to different understandings of the problems of unsustainable development.

The definition problem, then, is that we cannot say in any detail the exact make-up of dynamic human and natural sustainability. Much of the debate about definitions is actually about the different aspects of sustainability that authors have focused on. There is a common thread, however, in that humanity's current development path is not sustainable. The changes necessary if we are to move to a sustainable path will be substantial, and will not occur easily. There will be winners and losers. The combination of the "high-stakes" nature of the discussion and the shortage of detailed knowledge of how the human–ecosystem relationship works has contributed to a long and ongoing debate about the definition of sustainable development.

Rather than engage in such debate, it is practical for this report to state simply that definitions of sustainable development must incorporate aspects of economic and ecological sustainability along with human well-being, and proceed on to measurement issues. Each approach discussed in Chapter 2 is a response to the real need to try to measure progress, despite definitional uncertainties.

CHAPTER 2: MEASUREMENT AND INDICATORS

Need for Measurement

There are many reasons for measuring progress toward sustainable development, ranging from a general commitment to the environment and sustainable and equitable use of natural, human and social resources through to a specific commitment to more efficient government operations and the very concrete commitment to institutional accountability.

The Canadian government's commitment to institutionalize sustainable development performance reviews makes measurement a priority. The increasing need for measurement is an expected outcome of the new office of Canada's Commissioner for the Environment and Sustainable Development which requires reports on progress toward sustainable development from every federal department.

Measurement is indispensable to make the concept of sustainable development operational. It helps decision makers and the public define sustainable development objectives and targets, and assess progress made in meeting those targets. Measurement also helps in making policy choices and the necessary policy corrections in response to changing realities. It provides an empirical and quantitative basis for evaluating performance and making comparisons over time and across space, and it offers an opportunity to find new correlations.

The primary goal of measurement is to help decision makers evaluate their performance in achieving goals and targets. Measurement also provides a basis for planning future actions. For these purposes, decision makers need tools to connect past and present activities to future goals. Indicators are central among these tools.

Thus, measurement is useful for decision makers particularly because it helps:

- understand what sustainable development means in operational terms (In this sense, measurement and indicators are *explanatory tools*, translating the concepts of sustainable development into practical terms.);
- make policy choices to move toward sustainable development (Measurement and indicators create linkages between everyday activities, and sustainable development. indicators provide a sense of direction for decision makers when they choose among policy alternatives: they are *planning tools*.); and
- decide how successful efforts are to meet sustainable development goals and objectives (In this sense measurement and indicators are *performance assessment tools*.)

To translate sustainable development from concept to practice, one must understand the human and natural processes that create environmental, financial or social problems. We also need information on the extent of these problems. At the same time, new and better solutions to problems and opportunities must be found to improve the situation. The next task is to mitigate or eliminate the identified problems and implement new solutions. Thus, there are three issues to be addressed in the measurement process:

- activities that create problems in local ecosystems and the global environment, in the national and local economy, and in communities and individuals;
- the resulting changes in the ecosystems, economy, communities and individuals, both short and long-term, reversible and irreversible; and
- policy responses, their extent and impact.

As discussed earlier, these issues are not fully defined. As a result, decisions about what to measure must be based on judgments about what is important, in the absence of full knowledge. These judgments differ according to the situation and because people use differing definitions of sustainable development. While it would sound more logical to agree on a definition before deciding what to measure, in practice both discussions are going on simultaneously. This reflects the real need for measurement tools, especially ones that help deal with uncertainty.

Indicators

Definition of Indicators

Indicators are signs or signals of complex events and systems. They are bits of information pointing to characteristics of systems or highlighting what is happening. The term “indicator” comes from the Latin verb *indicare*, which means “to disclose or point out, to announce or make publicly known, or to estimate or put a price on” (Adriaanse, 1993; Hammond et al., 1995). Indicators are used to simplify information about complex phenomena, such as sustainable development, in order to make communication easier and, frequently, quantification possible.

An indicator can be a variable (e.g., the total amount of organically farmed products) or a function of variables (e.g., a ratio, such as recycled vs. total amount of solid waste). An indicator can be a qualitative variable (e.g., safe–unsafe neighbourhood, participatory–non-participatory decision making), a ranking variable (e.g., best or worst training program, lowest or highest mortality rate) or a quantitative variable (e.g., energy use in kilowatt hours/year, gross domestic product/capita).

Though quantitative indicators are the most widespread, qualitative indicators are also important when the issue to be measured is non-quantifiable (e.g., cultural values), when the information is based on opinion surveys (e.g., yes or no answers to questions such as "Are you satisfied with your situation?" or "Do you participate in conservation programs?"), when quantitative information is not available (data are missing) or when high costs prohibit the use of quantitative indicators or when a simple signal, such as a red light on an instrument panel or dashboard, is sufficient to initiate action.

Most existing indicators have been developed for specific reasons: they are environmental, economic, social and health indicators that are not considered sustainable development indicators *per se*, but which have an explanatory value within the context of a sustainable development framework. Complex problems of sustainable development require integrated or interlinked sets of indicators, or an aggregation of indicators themselves. There are a few, mostly experimental aggregated indicators (see Chapter 3) that make the linkages among the different issues of sustainable development explicit; they have been developed for that purpose and can be considered sustainable development indices.

Function of Indicators

Considering their function, indicators can be distinguished as system (sometimes called descriptive) indicators or performance indicators. System indicators summarize sets of individual measurements for different issues characteristic of the ecosystem and the human/social system, and communicate the most relevant information to decision makers (UNEP and DPCSD, 1995). System indicators are based on technical and scientific insights, whenever possible.

In the best case, information carried by system indicators would be determined by science. Unfortunately, the inherent uncertainties of natural systems usually make insistence on "beyond a doubt" proof impractical. Therefore, the standards and benchmarks to which indicators are related are determined only partially by science, and to a considerable degree by the policy process. Consequently, indicators themselves are also the products of a compromise between scientific accuracy and the needs of decision making, and urgency of action. This limitation becomes quite clear in the social dimension where many of the variables, such as political stability, cultural aspirations and equity, are hardly quantifiable and cannot even be defined in physical terms. Nevertheless, whatever level of accuracy is achieved in defining the indicators, it remains a realistic goal to measure them consistently and in a comparable manner across time, space and organizations in order to determine trends.

Performance indicators are tools for comparison, incorporating a descriptive indicator and a reference value or a policy target. They provide decision makers with information on how they are doing with regard to local, national or international goals, targets and objectives (UNEP and DPCSD, 1995). These indicators are used on all spatial scales and, in particular, in the policy evaluation phase of the decision-making process. They have a role in setting an organization’s objectives and linking them to actions.

Sustainable Development Indices

A specific type of indicator, presenting highly condensed information obtained by aggregating data, is called an index. High-level decision makers (e.g., ministers and heads of agencies) often ask for a very limited number of indices which are easy to understand and use in decision making. A typical example of an index is the gross domestic product (GDP), used by decision makers all over the world. It provides information on the total value of production in a country in one single index. Another well-known example is the Human Development Index (HDI), which contains indicators representing three equally weighted dimensions of human development: longevity (life expectancy at birth), knowledge (adult literacy and mean years of schooling) and income (purchasing power parity in dollars per capita and income above the poverty line) (UNDP, 1996).

To develop an index, the different indicators contained in the index need to be weighted according to their relative importance. In the case of the GDP, the weighting factor is the monetary value of the goods produced. However, when considering environmental, social and institutional aspects, this becomes a major problem since many of those goods cannot presently be given a monetary value. Instead, natural resources, for example, can be valued by estimating their potential value for the world population or the population in a given region or country. Other experts argue that an economic value should not be estimated and, instead, the different elements should be weighted according to scientific knowledge. For example, emissions of different greenhouse gases could be weighted according to the impact of the different gases on the climate.

While indices are necessary and aggregation of information is unavoidable, certain limitations should be kept in mind when working with indices. Besides the problem of weighting, there is the loss of analytical power: when valuation is based on less detailed information, the complexity of the link between the index and the real world might not be fully reflected. It is then possible that the index will be used to evaluate something it does not actually measure. An example is using the GDP to measure overall wealth while it actually only measures economic output.

The growing use of indicators reflects the recognition by both developed and developing countries that indicators are essential tools for decision making, to understand

and monitor trends and the effectiveness of policies and actions. They are also useful in identifying the relevance of data and possible gaps in data collection at different levels (international, regional, national or local assessment) and in establishing a conceptual framework and institutional arrangement for compiling and analyzing data.

CHAPTER 3: SURVEY OF ONGOING WORK IN MEASURING PROGRESS

> Commonly used indicators such as the gross national product (GNP) and measurements of individual resource or pollution flows do not provide adequate indications of sustainability. Methods for assessing interactions between different sectoral environmental, demographic, social and developmental parameters are not sufficiently developed or applied. Indicators of sustainable development need to be developed to provide solid bases for decision-making at all levels and to contribute to a self-regulating sustainability of integrated environment and development systems (Agenda 21, 1992, section 40.4).

This chapter provides a set of practical examples of the best known or most promising experiments with sustainable development measurement approaches and indicators worldwide — a kind of map of measurement tools. It excludes experimental and theoretical approaches that have not been tested. The survey groups the examples proceeding from international through national and sub-national practices to local and corporate practices. The examples have been carefully selected to represent all major trends of contemporary indicator work. While this study is not intended to explain what and how a government department can use the examples, there is a brief analysis of the advantages and limitations of each example from the viewpoint of practical applicability. There is also a summary of potentially applicable features a kind of compass for orientation — to make an eventual selection of methods and indicators for departmental application easier. It should be kept in mind, however, that no specific sustainable development measurement formats or indicator sets have been developed yet for the direct purpose of measuring the performance of a particular decision-making body. All sustainable development measurement approaches and indicator suites have been designed to assess performance through measuring the changes in the external world (environment, economy, society, human beings) attributed to the impact of policies and decisions made. Moreover, an important point to make is that *the methodology of measuring "sustainability" or "sustainable development performance" is not standardized. There is no textbook which gives a methodology that is generally accepted and applicable across regions and sectors.*

Application on the International Level

Three significantly different approaches are included in the following survey. The first is the indicator framework of the UN Commission on Sustainable Development (UN

CSD) used by national governments to measure their progress in implementing Agenda 21, the set of recommendations of the UN Conference on Environment and Development in 1992. This is the most ambitious and widespread program to date with a commonly shared set of traditional indicators to assess sustainable development performance. It has moved beyond the initial stage of developing a set of indicators and is already in the testing phase. Where applied, it enjoys the official support of national governments.

The second approach is developed by the World Bank, originally to measure the wealth of nations but also interpreted as a tool to measure progress in sustainable development. It is based on an innovative framework, but is still in an experimental stage. The very fact, however, that the integration of ecological, economic and social issues in a sustainable development measurement structure is promoted by the World Bank, which will potentially employ it in evaluating the impact of the Bank's development policy, makes the approach important.

The third approach is simultaneously applied by the UN Division of Statistics and several national statistical offices, including Statistics Canada. Its focus is the integration of environmental and economic issues in a measurement structure that is based on the correction of the System of National Accounts. It is a useful first step in the integration of the main issues of sustainable development and, while it is restricted to monetized indicators, its importance is that the approach is directly linked to the budgetary process and is easily comprehended and potentially supported by key economic decision makers, such as ministries of finance, industry and trade.

UN CSD Indicators

Agenda 21, the action program recommended by the 1992 Rio Summit, calls for countries, international organizations and non-governmental organizations to develop and use indicators of sustainable development. The UN CSD in 1995 adopted a work program on sustainable development indicators. The program, co-ordinated by the UN Department for Policy Co-ordination and Sustainable Development, (UN DPCSD), includes a list of over 140 indicators grouped according to the chapters of Agenda 21 in four major sectoral categories: social, economic, environmental and institutional indicators. These categories create the horizontal structure of a matrix in which the vertical structure is organized in categories called driving force, state and response (DF/S/R). Based on perceived causal relationships between stress-generating human activities and changes in the state of the environment (both natural and social), the DF/S/R framework presumes that with adequate responses (policy changes), the impacts can be mitigated and/or prevented. In this framework, driving force indicators represent human activities that affect sustainable development; state indicators show the condition and status of sustainable development; and response indicators reflect policy options and other reactions to changes in the state of sustainable development (published in the so-called Blue Book, UN CSD, 1996). This framework is viewed as the first phase in an iterative process and changes in the structure of the working list are expected over the next few years.

Wherever possible, indicators are developed to measure each component. For example, for an environmental indicator (Chapter 9 of Agenda 21, “Protection of the atmosphere”):

- driving force - emissions of greenhouse gases (e.g., CO_2 emissions);
- state - results in ambient concentration of pollutants (e.g., CO_2 concentration in urban areas); and
- response - level of expenditure on air pollution abatement (e.g., carbon tax).

The UN DPCSD asked several agencies and institutions to develop methodology sheets through a broad international consultation for the application of the indicators.

The uniform methodology sheets are very useful tools, providing a description of the following information:

- indicator definition (name, brief definition, unit of measurement);
- place in the framework (relevant chapter of Agenda 21, type of indicator);
- significance and policy relevance (purpose, relevance to sustainable/unsustainable development, linkages to other indicators, targets, relevant international conventions and agreements);
- methodological description and underlying definitions;
- assessment of the availability of data from international and national sources;
- agencies involved in the development of the indicator; and
- further information, including bibliography of sources.

The DPCSD developed guidelines for the implementation of the indicator set, and 12 countries volunteered to test the indicators in their national reporting to the UN CSD. The test phase will last for two years when the whole set, the methodology sheets and the usefulness of the approach will be evaluated.

Table 1
The CSD Framework of Indicators of Sustainable Development

Category	Chapters Of Agenda 21*	Driving Force Indicators **	State Indicators **	Response Indicators **
Social	Chapters 3, 5, 36, 6, 7			
Economic	Chapters 2, 4, 33, 34			
Environmental	Chapters 18, 17, 10, 12, 13, 14, 11, 15, 16, 9, 21, 19, 20, 22			
Institutional	Chapters 35, 37, 8, 38, 39, 40, 23-32			

Notes:
* The chapter numbers are listed in their sequence of occurrence in the UN CSD list.
**The boxes contain 130 indicators, detailed in the Blue Book (UN CSD, 1996).
Source: UN CSD, 1996.

Advantages: Grouping indicators in parallel to the chapters of Agenda 21 is practical as they cover the issues that have been emphasized by this document. It also relates to the program framework applied by many national governments and an increasing number of local authorities. The grouping of the chapters into four main categories corresponding to the generally accepted themes of sustainable development (economy, environment, society and institutions) is also useful. The matrix presentation is simple and easy to handle. The list of indicators may be viewed as a menu from which individual users can select a set that best fits their needs.

The methodology sheets developed by the CSD are the most useful part of its approach and, as a general template, they can be applied in almost all measurement projects. The sheets also help clarify the indicators and make their use more precise. The DF/S/R model is simple and powerful, as long as the causal linkages among the three dimensions are clear, especially for biophysical indicators.

Limitations: As the UN CSD indicator set includes more than 140 indicators, it is not possible to recommend a short list of the potentially most useful indicators. (For a full list of indicators see Appendix A, Table A1.) The high number of indicators makes the set unfit for decision-making purposes and, since there is no attempt at aggregation, it does not provide a measure of progress. Most important, it does not offer measures for the linkages among the issues. It lacks a holistic perspective and does not offer a method for selecting from the offered menu. It has a disproportionate focus on environmental/biophysical indicators.

A serious limitation of the approach is the DF/S/R model itself. It does not work if scientific evidence for causal linkages is missing, and it oversimplifies inter-linkages and relations among issues. Often, it is ambiguous whether the issue measured by an indicator represents a driving force or a state. For example, unemployment (measured by unemployment rates as an indicator) might be considered a driving force triggering policy responses or a state that reflects the impact of a wrong economic policy. Also, there are multiple pressures for most states, and multiple states from most pressures. For example, sulphur dioxide causes not only acid rain but also urban air pollution that counter the warming effect of greenhouse gases. Fish populations are affected not only by fishing, but also by pollution and weather, and perhaps global warming. Furthermore, a change in one fish population, by altering nutrient availability or competition patterns, will change another fish population.

Relevance to Users: The guidelines provide:

- methodology sheets;
- grouping of indicators along the chapters of Agenda 21 (within the main categories); and
- a menu for choice from detailed description of six clusters of indicators:
    - land and deforestation indicators;
    - water and atmosphere indicators;
    - other natural resources indicators, waste and chemical indicators;
    - economic and finance indicators;

- science, information, education, gender, technology and institutional indicators; and
- other social indicators.

The World Bank's Measure of the Wealth of Nations

In 1995 the World Bank started experimental work to monitor progress in environmentally sustainable development (World Bank, 1995, 1996). The Bank has attempted to measure the wealth of nations by measuring natural resources (the natural capital) relative to produced assets (or human-made capital) and human resources (the social and human capital). The approach presumes that sustainable development is a process of creating and maintaining broadly conceived wealth. The notion of wealth is extended from natural and produced wealth to human and social capital. There is a stock of health, skills and knowledge contained within human beings that can be invested in, enhanced, and used to produce a steady stream of productivity, or that can be overused, eroded and allowed to depreciate. There is also an equivalent social capital in the form of law and order, functioning civic organizations, cultures of personal and community responsibility, efficient markets and governments, tolerance and public trust.

The approach uses aggregation and monetization to compare data and rank nations according to the cumulative value of their capitals. Capitals are measured through a selected number of indicators, mostly taken from the realm of integrated economic and environmental accounting.

- Natural capital is measured through six components: agricultural cropland, pasture land, timber, non-timber forest benefits, protected areas and non-renewable materials (metals, minerals, oil, coal, gas).
- Human-made capital or produced assets are measured in the categories of fixed capital formation, including machinery and transport equipment, building and construction and urban land.
- Social capital is measured along relationships and institutions of a society (horizontal associations such as the number and type of local institutions, civil/political society such as the index of civil liberties, social integration such as social mobility or crime, and legal/governance aspects such as the independence of the court system) and the types of impacts social capital has on the development process (growth, equity and poverty alleviation).
- Human capital is measured along acquired skills (e.g., education) and health (e.g., life expectancy).

Indicators have been selected to represent the above categories in a way that monetized values could be assigned to each indicator. Trends are measured by genuine saving as a percentage of adjusted gross national product (where adjustment includes depletion of natural resources and damage caused by pollution as minuses, and spending on education as a plus).

Advantages: The framework offers a holistic approach and puts a major emphasis on the linkages among the main dimensions of progress and the complementary character of these dimensions. Extending the definition of capital to natural, human and social capital is an easily understood and powerful concept that could link sustainability and development, and provide a dynamic, whole-system approach. The concept of capital allows the stock-flow analysis that can make indices dynamic. It is future oriented, deals with trends and has clear policy relevance. It is pioneering in defining indicators for social capital, taking into account the institutional structures and accumulated experience of communities. It offers a harmonized calculation method, expressing the indicators in comparable monetized terms, and makes aggregation easy. The methodology is based on the balance sheet calculations of national accounts, providing understanding for key economic policy makers.

Limitations: The approach applies several innovative ideas that are not well tested yet. The concept of social capital, in particular, needs further refinement and better dimensions for measurement. The methodology focuses entirely on monetized values and only measures those segments of sustainable development that can be expressed in monetary terms. Indicators are not presented in matrix format, and the structure of presentation is not transparent. The detailed calculations of indicators are highly technical and difficult to handle.

Relevance to Users: The framework allows for:

- grouping indicators along the four capitals (natural, human-made, social and human);
- use of social indicators by the types of impacts social capital has on the development process (growth, equity and poverty alleviation);
- use of human capital indicators (education expenditure and life expectancy);
- genuine saving as a trend indicator;
- use of aggregated and monetized data; and
- balance sheet calculations based on a modified system of national accounts.

Corrections of the System of National Accounts

It is often argued that economic measures, such as the GDP, give an incomplete picture of welfare and development. The GDP only measures the economic wealth in a society, but fails to measure environmental, social and institutional wealth. The international debate has contained many proposals for bringing these elements into the System of National Accounts (SNA) (World Bank, 1993; Bringezu et al., 1994). In the SNA, transactions should be measured by market prices and/or a real flow of money. In recent years, considerable efforts have been made at the international level to promote the integration of economic and environmental accounting and to develop methodologies in this area. Current work concentrates in four main areas: adjustments of the SNA, creation of satellite accounts, creation of specific national resource or environmental accounts and creation of environmental accounts at the micro level (UN DPCSD, 1996). These experiments are not to create new indicator sets. Rather, they use existing indicators in a new context.

Discussion at the macro-economic level has focused on how the SNA can be adjusted to account for environmental values; more specifically, on how to calculate a "Green GDP." The adoption of an international consensus for a framework and reference for the calculation of a Green GDP is an overall emerging priority, in order to facilitate the implementation of the concept in practical terms. Only a few countries have attempted such work and their experiences vary, reflecting the different objectives of the countries concerned as well as different approaches.

In the absence of an international consensus on how to incorporate environmental assets and the cost and benefits of their use into the internationally adopted SNA, the United Nations Statistical Division developed its System of Integrating Environment and Economic Accounting (SEEA) in 1993. Several industrialized and developing countries are experimenting with the implementation of satellite accounts through the application of the SEEA framework to the specific national context. Progress has been made in implementing it within countries in the Organization for Economic Co-operation and Development (OECD) region including water accounts in Spain, (combining information on water quality and quantity with information about expenditure on water pollution abatement and mobilization of resources) and water accounts in France, forest accounts in Japan, energy accounts in Norway, crude oil and natural resource accounts in Canada and accounts of natural resources in Indonesia and China.

Statistics Canada has been working for the last decade to elaborate satellite accounts to better capture the relationship between the economy and the environment, without fundamentally changing the System of National Accounts. This work has resulted both in practical and theoretical findings particularly in accounting for natural resources, valuation of non-renewable resources and in environmental statistics. Parallel to this work, the Occupational and Environmental Health Research Section of Statistics Canada developed statistical and policy-relevant information on socio-economic and environmental factors affecting the health of individuals. Statistics Canada, however, has not yet focused its research or data collection activities specifically on sustainable development.

Other initiatives include a manual to be prepared by EuroStat at the request of policy makers in Europe, and preliminary drafts are being prepared by different UN agencies. Taking into account the level of methodologies and their complex nature, formulation of a clear practical set of guidelines or manual for the application of the SEEA is considered essential and has been called for by a growing number of countries. At the micro-economic level, international as well as national accounting standard-setting bodies are making progress in looking at contingent liability and disclosure requirements for environmental impacts in annual business reports, and a growing number of firms now refer to environmental practices in their annual financial statements.

Advantages: As environmental data related to individual economic sectors can yield valuable insights for resource managers in the involved sectors, national resource accounts are becoming an increasingly popular tool for policy analysis. The SEEA is building on sections of the satellite accounts and is acceptable for economic decision makers. The method has the capacity to integrate indicators that reflect the depletion of natural capital into economic decisions. It may move business closer to goals such as cleaner production and eco efficiency. Statistical services provide an excellent empirical data base for developing sustainable development indicators.

Limitations: The corrections to the SNA do not deal with indicators *per se*; the focus is on how to integrate sub-systems, each using its own set of indicators, into the full accounting system. The SEEA focuses exclusively on the relationship of economic and environmental (mostly biophysical and resource) issues; human and social dimensions are not included. There has been little progress in developing integrated environmental and economic accounting (IEEA) at the national level. Conventional national accounts have provided indicators for assessment of economic performance and trends for several years, but the emphasis in integrating environmental information into this process is relatively new, and it remains controversial. Further development of resource inventories as well as "sensitivity mapping" of natural resources is needed in order to identify areas of high risk or vulnerability.

Relevance to Users: The System of National Accounts corrections would promote:

- integration of economic and environmental accounting;
- calculation of a "Green GDP";
- national resource accounts, including indicators that reflect the depletion of natural capital (water, forest, energy and crude oil accounts); and
- an empirical data base for developing sustainable development indicators.

Applications on the National Level

After the Rio Summit in 1992, national governments pledged to report their progress toward sustainable development to the UN CSD annually. In an effort to make this report more tangible and empirical, the UN CSD initiated its indicator program described above. At present, 12 national governments are committed to test the UN CSD indicator set in the field. A handful of governments, however, started their sustainable development measurement programs independently from the UN program and have made progress in using sustainable development indicators. The most significant results have been achieved to date by the Canadian, Dutch and U.K. governments. The work of the former two is presented here, accompanied by the approach taken by the U.S. President's Council on sustainable development which, though not yet tested in reality, offers important insights into the design of sustainable development indicators.

Canada — National Set of Indicators

There are two, conceptually different approaches to sustainable development measurement frameworks and indicators for national use in Canada. One is based on many years of work in environmental reporting and is harmonized by the Indicators, Monitoring and Assessment Branch of Environment Canada (EC). The other is based on the work of the National Round Table on the Environment and the Economy (NRTEE) to define a new approach to assess progress toward sustainable development.

Environment Canada is charged with developing and reporting regularly on a comprehensive national set of environmental indicators that gives a representative profile of the state of the environment, and helps measure progress toward sustainable development. The national set is guided by the principal goals for sustainable development, and focuses on significant national issues (some of which are also global, e.g., climate change) (Environment Canada, 1991). Work to elaborate technical specifications for a core set of environmental indicators is progressing with federal and provincial jurisdictions, and with OECD member countries. Environment Canada is also engaged in the UN CSD sustainable development indicator initiative. Indicators are grouped by a modified version of the pressure-state-response (PSR) framework, similar to the UN CSD indicator set. In the Environment Canada version, pressures include driving forces (e.g., demographics and technology change), human activities (e.g., use of natural resources) and stresses (e.g., contaminant discharge), while responses include ecological reactions to stress (e.g., the loss of biodiversity) and management responses (e.g., regulations).

Canada also supports an ecological framework for reporting using sustainable development indicators. Canada is simply too large and ecologically diverse to have, in many instances, one indicator for the entire country. To this end, Canada has developed a hierarchical ecological framework for the country. At the most general level, there are 15 terrestrial and five marine ecozones in Canada. These ecozones are further subdivided into more detailed ecological delineations. For national reporting purposes, pertinent indicators are reported at the ecozone level. To date, 18 issue areas have been included in the national set of indicators (see the full list in Appendix A, Table A2). These are the following:

- atmosphere (climate change, stratospheric ozone depletion, radiation exposure, acid rain, outdoor urban air quality);
- water (freshwater quality, toxic contaminants in the fresh water ecosystem, marine environmental quality);
- biota/living organisms (biological diversity at risk, state of wildlife);
- land (protected areas, urbanization, solid waste management); and
- natural economic resources (forestry, agriculture, fisheries, water use, energy).

Eighteen indicator bulletins have been released covering 10 of the issues. Technical supplements, which provide the data and descriptions of data accuracy, methodologies and sources of information, are provided with each indicator bulletin.

Undoubtedly imperfect and incomplete, it nonetheless shows how the search has moved from the purely theoretical to concrete efforts to identify, describe and assess specific indicators that might prove useful.

While the focus of Environment Canada's work is on the environment, the department has incorporated indicators developed by other agencies to report on aspects of sustainable development and to influence decision makers. These include:

- *Report on Human Activity and the Environment* produced by Statistics Canada (1995);
- *Report on the Health of Canadians* prepared for the Ministers of Health by the Federal, Provincial and Territorial Advisory Committee on Population Health (1996);
- *Defining Sustainable Forest Management: A Canadian Approch to Criteria and Indicators* produced for the Canadian Council of Forest Ministers by an interdepartmental and non-governmental Technical Advisory Committee (1995); and
- various state of the environment reports produced by several provinces.

In addition, Statistics Canada, through the composite leading index, routinely reports on eight components of the economy. Component leading indicators cover industrial production as well as demand for services and are closely aligned with the business cycle.

Advantages: The indicators are developed from readily available data, primarily from national survey and monitoring programs. The presentation of issues of national significance uses simple graphics. Target values and standards are included where they have been established. The ecozone approach provides a better classification for indicators in a diverse setting. The measurement process relies on multi-stakeholder participation to achieve a balanced and widely accepted assessment.

Limitations: The set of indicators focuses almost exclusively on environmental issues. The inclusion of non-environmental indicators is anecdotal and does not provide a basis for measuring linkages. It does not offer a consistent framework for sustainable development measurement. The grouping along the categories of the PSR framework is sometimes arbitrary and ambiguous. The ecosystem thinking is relevant only in the regional case studies, not in national reporting.

Relevance to Users: The national set of indicators approach offers:

- selection of issues of national importance;

- multi-stakeholder participation in the selection of issues;
- ecozone approach for environmental indicators;
- use of pertinent indicators for changes (in atmosphere, water, biota, land and natural resources); and
- well-established methodology to measure environmental trends.

Canada — NRTEE Linked Human/Ecosystem Well-Being Approach

Between 1991 and 1995, the NRTEE's Task Force on Sustainable Development Reporting examined the ability of Canadians to monitor, assess and report on progress toward sustainable development and addressed long-term issues of the conceptual and theoretical complexities of reporting. It defined a new, whole-system approach to a set of indicators that captures the values implied by sustainable development, particularly a parallel concern and respect for the ecosystem and the people within, constituting a whole (NRTEE, 1995). The approach emphasizes four main areas of assessment:

- the integrity and well-being (or health) of the ecosystem;
- the well-being of people defined in the broadest sense (including individuals, communities, nations, etc.) and the assessment covering physical, social, cultural and economic attributes;
- the interaction between people and the ecosystem (how human activities stress or restore the ecosystem, how successful humans are at meeting policy goals and objectives); and
- the synthesis of the above three components and the linkages across them.

The selected indicators which span a wide range of disciplines, gained prominence because of earlier use, though they are put in a new context. Instead of replacing existing reporting elements, they build on what has already been developed. Together they form a family of sustainable development indicators that helps synthesize a broad picture (see Appendix A, Table A3 for a partial list of these indicators).

The linked human/ecosystem well-being approach has been tested in a report on British Columbia's progress toward sustainability (1997). Human well-being has been assessed along five major dimensions:

- the wellness of individuals, families and households;
- the strength and resilience of communities;
- the diversity and success of various businesses;
- the effectiveness of government; and
- the vibrancy of the economy.

Individual indicators were converted to a performance scale of 0-100, 0 meaning worst and 100 meaning best. End points have been defined by an international comparison of desirable values for each indicator. Individual performance values then were combined, establishing an index of human well-being.

Ecosystem well-being which has been assessed traditionally along five major dimensions:

- land
- water
- air
- biodiversity
- resource use.

Using the same method of conversion to a performance scale as for the human well-being indicators, 245 individual performance indicators of the ecosystem have been combined into an index of ecosystem well-being. Finally, the two indices have been plotted together in a matrix of performance scale. This final step of evaluation is identical to the method used in the calculation of the Barometer of Sustainability index described below.

Advantages: The use of systems thinking and a holistic approach is a distinctive characteristic of the method. Constituent parts are referred to the whole system and are integrated to provide a full description of the system. Linkages and interactions are clearly emphasized. Indicator selection reflects the priority of the relationship to wellness. The main indicator dimensions are representative and well grouped. The social and human dimensions get equal emphasis with the economic and ecological ones. The conversion to a performance scale provides easy evaluation and makes aggregation simple.

Limitations: The practical application of the approach is uneven; indicators are best developed for the human and the ecosystem areas of assessment, but scattered for the interaction area and completely missing for the synthesis area. The projection to the performance scale is arbitrary and occasionally missing. Within the selected dimensions, too many indicators are presented, making a concise evaluation difficult.

Relevance to Users: The human/ecosystem approach offers:

- a whole-system approach;

- a focus on people's and ecosystems' well-being;
- dimensions of indicator selection;
- indicators of linkages;
- use of aggregated indices such as the index of human well-being and the index of ecosystem well-being; and
- conversion to performance scale.

The Netherlands — Policy Performance Indicators

The Netherlands ministry of housing, physical planning and environment has developed a set of environmental policy performance indicators which enables decision makers to evaluate the implementation of the country's National Environmental Policy Plan (NEPP) (Adriaanse, 1993). This set of indicators extends to the linkages between the environment and economy and, consequently, is used as a starting set to measure progress toward sustainable development.

The indicator set comprises two subsets, focusing on issues and sectors of assessment. The set of issues includes so-called theme indicators; the set of sectors includes so-called target group indicators. The themes are:

- climate change (greenhouse effect, depletion of the ozone layer);
- acidification of the environment;
- eutrophication of the environment;
- dispersion of toxic substances;
- disposal of solid waste; and
- disturbance of local environments.

The selection of themes was based on the priorities of the NEPP and reflects a concern for the physical quality of the environment and its impact on human health. Each theme is measured by one theme indicator which is an aggregation of the main contributing components. The climate change indicator, for instance, is aggregated from emission data of the most important greenhouse gases (carbon dioxide, methane, nitrogen oxides, chlorofluorocarbons and halons); the eutrophication indicator is aggregated from phosphate and nitrate emissions; and the indicator of dispersion of toxic substances is aggregated from emission data of agricultural pesticides, other pesticides, priority substances (cadmium, mercury, dioxin, etc.) and radioactive substances. The same method has been applied for all the other theme indicators.

The method of aggregation deserves special attention as it is a unique feature of the NEPP approach. The starting point is that the environmental load is not caused by a single substance but by the combined impacts of several substances. The contribution of the components is weighted according to their relevance before they are added up. For example, a given volume of Halon 1301 damages the ozone layer more than 10 times as much as the same volume of the standard reference substance, chlorofluorocarbon CFC-11. The emission of Halon 1301 is therefore given a 10 times greater weight in calculating the indicator. For comparison purposes, a so-called theme equivalent has been developed for each theme indicator. In the case of climate change, for instance, the impact of each contributing greenhouse gas has been expressed as the equivalent global warming potential of carbon dioxide (in other words: how much carbon dioxide would produce the same warming effect), and a carbon dioxide equivalent has been calculated and added to the theme equivalent.

While the calculation of the theme indicators seems to be complicated, the result is simple. They are presented in a single graph, showing the course of total environmental pressure plotted against time. Percentage of change can be calculated by comparing data of the time series to an arbitrarily selected standard year (in the Netherlands case, 1980).

The use of an environmental pressure equivalent as an intermediate level of aggregation of information results in the use of an identical unit to express environmental pressure in each theme. As this unit has no dimension, it is easy to aggregate the pressure equivalents of the themes. The total sum of these equivalents is the environmental pressure index for the Netherlands.

To provide integration of environmental and economic analysis, the second part of the indicator set deals with the economic sectors. The purpose of analysis here is to measure the contribution of each selected sector to the environmental pressures along each of the previously analyzed themes. Seven target sectors have been selected:

- agriculture (measured in annual production value);
- traffic and transport (measured in annual traffic performance by road traffic);
- industry (measured in annual production value);
- energy sector (measured in annual electricity production);
- refineries (measured in annual throughput in crude oil);
- building trade (measured in annual production value); and
- consumers (measured in annual consumption value).

Consequently, a respective target group indicator shows how much environmental pressure is attributed to a single sector. In the case of agricultural production, for instance, the target group indicator sums up its annual contribution to acidification, eutrophication and dispersion. Finally, the same way as the theme indicators have been aggregated to an index, the relative contributions of the target groups to the total environmental pressure have also been aggregated into one target group index.

Advantages: The selection of a concise set of themes offers a reliable calculation of quantitative indicators. The two sets of indicators help measure the linkages between the environment and economy and provide a useful method of aggregation. The application of environmental pressure equivalents makes comparisons meaningful and trend presentation easy. The aggregation method results in simple indices that are informative and can be easily communicated to decision makers. The aggregated indices can be used for measuring progress in meeting policy goals. There is potential to apply the methodology (*mutatis mutandis*) to other sectors and to social themes as well.

Limitations: The focus is predominantly on environmental loads and pressures. Quantitative indicators are used exclusively. The weighting procedures fit well only when scientific evidence exists for calculating equivalents. The aggregate index can be meaningfully used only when policy targets are numerically established.

Relevance to Users: The NEPP set of indicators provides:

- selection of a concise set of themes;
- method of aggregation;
- use of equivalents to eliminate incompatible dimensions;
- environmental pressure index;
- time series to measure distance from targets; and
- selection of economic sectors for measurement.

United States — President's Council on Sustainable Development Indicator Set

The U.S. President's Council on Sustainable Development established the Inter-Agency Working Group on Sustainable Development Indicators in 1994. The Group first addressed the issues of information collection and the process of selection. In 1995, it published a draft prospectus on the formalization and enhancement of its work. The prospectus included a preliminary indicator framework that was refined by the time the first report of the Council (President's Council, 1996) was published. The report identified a set of progress indicators for each of the 10 general goals of sustainable development identified in the report (see Appendix A, Table A4).

The refined framework defines an inventory of potential sustainable development indicators out of which the Working Group, based on widespread consultations, selects a list of proposed indicators. That list is matched to actual data, and the final list of sustainable development indicators is established. The selection process repeats annually to focus on emerging priorities.

The framework integrates three major components.

- Endowments are capacities inherited from past generations and transferred to the future.
- Processes are activities that act on endowments to produce current results. Driving forces are a subset of processes that directly act on endowments. Decision making is a subset of processes that determine human actions.
- Outputs and results are goods, services and experiences resulting from using endowments.

Endowments have a meaning similar to that of the four capitals in the World Bank's approach and are grouped into economic, environmental and social endowments. Processes are the centrepieces of this approach and link the use of indicators directly to the decision-making process. Outputs and results are grouped into economic outputs, environmental services and social results. Each component is measured by indicators; a total of 32 indicators is suggested (see Table 2). The proposed indicators are described in detail (see Appendix A, Table A5), though no data collection and reporting activities have been started yet.

Advantages: The Inter-Agency Working Group's set of indicators is organized in a logical way that reflects a holistic approach to sustainable development and decision-making priorities. The number of proposed indicators is small enough for convenient use. The indicators themselves are easy to measure, based on existing capacities and are representative to issues of major concern.

Limitations: The selection of indicators reflects a special focus and an arbitrary ranking of issues that are not necessarily shared by others not involved in the process. The distinction between process and outcome indicators is ambiguous and occasionally does not have practical significance. Real life testing is missing.

Relevance to Users: The set of indicators of the Inter-Agency Working Group on Sustainable Development Indicators provides:

- grouping of indicators as endowments, processes and outcomes/results;
- a focus for the measurement structure around the decision-making process;
- use of a limited number of representative indicators; and
- use of well-established, easy to measure indicators.

Table 2
List of the Inter-Agency Working Group on Sustainable Development Indicators

Proposed Sustainable Development Indicators for 1997			
Dimensions	Endowment Indicators	Process Indicators	Output/ Results Indicators
Economy	• Capital assets • Total managed waste • Work force skill level	• Energy consumption per capita • Investment percentage of GDP • Materials use per capita	• Consumption expenditures per capita • Income distribution
Environment	• Contaminants in biota • Greenhouse climate response index • Groundwater contamination • Major land use, including urban areas • Soil types • Species in trouble • Toxic land area • Water quality index	• Fish catch to growth ratio • Greenhouse gas emissions • Invasive exotic species • Ozone-depleting substances • Timber harvest to growth ratio • Water consumption to renewal ratio	• People in clean air non-attainment areas • Outdoor recreation services
Society	• Family function • Teacher capabilities • Total population	• Community group participation	• Crime rate • Population health • Receipt of health care • Test scores by economic group

Source: Berry, 1996.

Applications on the Sub-National Level

A rich source of experience in measuring progress toward sustainable development and working with indicators can be found in projects developed on sub-national levels especially at local community levels. Other projects have been designed and implemented at the state level in the United States, and at the provincial level in Canada. Still others focus on ecosystem rather than jurisdictional units, such as the Great Lakes Region or British Columbia's Southern Interior Ecoprovince.

Pioneers of sustainable development measurement include Colorado, Kansas, Maine, Minnesota and Oregon in the United States; the well-documented and trend-setting Oregon Benchmarks project has been selected for the present survey. In Canada, three provinces are experimenting in sustainable development reporting and indicator sets: Alberta, British Columbia and Manitoba. British Columbia's *Report on British Columbia's Progress Toward Sustainability* was published in 1997; Manitoba's pilot chapter on sustainable development reporting on the prairie ecozone will be published as part of the 1997 State of the Environment Report. As the B.C. approach was covered in the section on national applications in Canada (the linked human/ecosystem well-being method) and the Manitoba work is in progress, the Alberta experience is included in this section.

Alberta — Sustainable Development Indicators

The province's indicator project was initiated by the Alberta Round Table on the Environment and the Economy (ARTEE, 1992), after the Round Table identified nine basic vision elements for Alberta's sustainability in the future. Under the guidance of the Round Table's Indicator Working Group, an indicator project team co-ordinated a year-long exercise focusing on indicator identification as laid out in a project plan. The project plan also contained provisions for a review of indicator literature, development of a screening model and indicator criteria, design of a management system and consultations with Round Table members, specialists and other stakeholders.

A preliminary data base of more than 850 indicators was compiled based on polls and interviews with members of the ARTEE as well as different stakeholder groups. This list was later reduced in two steps to a final number of 59 on the basis of selection criteria, expert advice and literature data (see Appendix A, Table A6). Each indicator is presented with a short description, a rationale and source of data.

There are no explicit categories for organizing indicators. In principle, the project realized a different and causal linkage between driving forces of change and results of change, and assigned each vision element into one of these categories. Although the direction of linkages in terms of what is a cause and what is a result may be subject to discussion, the realization of connections and balances between various vision elements is important. Unfortunately, there is little discussion in the project of the methodological challenges that arise when decision makers attempt to address causal linkages between heterogeneous indicators in decision making. As of this date, quantitative indicators have not yet been reported.

Responsibility for co-ordinating data collection and regular indicator publication was assigned to the Alberta Bureau of Statistics. Soon after indicator identification was completed, however, the Bureau of Statistics was dissolved as part of the government's budget cutting efforts. This highlights the importance of finding the right institutional framework with long-term security in terms of human and financial resources and technical capabilities. This point is even more important considering that without reporting indicators over extended periods, no trends can be established. Without significant trends, it is impossible to link policy measures to changes in indicator values. Thus, any meaningful application of indicators for planning purposes may become unfeasible.

Advantages: Broad public participation helped identify the relevant issues of sustainable development for the province. A selection process has been applied for reducing a huge pool of indicators to a manageable number. Indicators are concisely described and explained. Visions and indicators are linked together.

Limitations: The grouping of the indicators lacks any structure; the selection of indicators seems to be very ad hoc and arbitrary. There are no linkages among the issues to reflect sustainable development. The presupposed causal linkages between causes and envisioned results are not discussed or proved. Implementation has not occurred.

Relevance to Users: The Alberta indicators offer:

- a measurement process design and indicator selection according to a project plan;
- the results of a broad public consultation and work with the Round Table; and
- a process of reducing a broad pool of potential indicators to a small size.

Oregon Benchmarks

The benchmarking process of the State of Oregon was initiated in the late 1980s, and by now has become a model for a number of state programs (Minnesota, Montana, Kansas). Although originally the Oregon Benchmarks process was not referred to explicitly as a sustainable development measurement exercise, several of its components are compatible with sustainable development principles and go beyond traditional environmental or economic reporting in five key ways.

- Indicators are identified by major stakeholders through a public consultation exercise instead of by only experts and government officials.

- Besides biophysical environmental indicators normally accounted for in State of the Environment reports, the Benchmarks process also considers social and economic indicators.

- Oregon Benchmarks not only provide historical and current values for a given indicator, but also report future targets quantitatively.

- The actual application of indicators is ensured by legal provisions approved by the State Assembly; specific measures include appointing an accountable senior government official to be responsible for each lead benchmark.

- Benchmarks are incorporated into the state budgeting process as important criteria in allocating resources (Oregon State Progress Board, 1992).

A key feature of the benchmarking process in Oregon is that besides continuous data collection for individual indicators, benchmarks are revisited every second year. Thus, the project ensures that the changing perceptions and values of the public, affected by most recent developments are also reflected in benchmarks for the future. In fact, it may be more accurate to consider the Oregon Benchmarks as an institution instead of a project that will be completed in the foreseeable future. A long-term view is also necessary because, in many instances, long time series of data are required to obtain statistically valid trends that are convincing enough to trigger policy action. As a sign of official commitment, primary responsibility for the Benchmarks rests with the Oregon Progress Board, headed by the state governor. In its multi-stakeholder structure, the Board may bear certain similarity to provincial round tables in Canada.

Indicator categories selected in the Oregon Benchmarks program are shown in Appendix A, Table A7. Altogether, there are 159 measurable indicators, for which, in principle, there are four data points available so far: 1970, 1980, 1990 and 1992. Benchmark projections are identified for 1995, 2000 and 2010. Among the 159 indicators, the most critical ones are identified as “urgent benchmarks,” and ones that are considered important for the longer-term sustainability are designated as “core benchmarks.”

Advantages: An institutionalized and participatory process is used to identify issues and related indicators. The application of measurement tools is ensured by legal provisions. It is open for changes and future-oriented. The most critical indicators are grouped as urgent benchmarks, and targets are set against which measuring progress is possible. Trends can be easily identified and projections made based on the trends. Budgetary allocation for measurement purposes is built into the state budget.

Limitations: There are too many indicators to deal with in the decision-making process. The selection of urgent benchmarks is relatively arbitrary, though it reflects community concerns. The classification of indicators is vague, and the 14 categories are not selected in a consistent manner.

Relevance to Users: The Oregon Benchmarks provide for:

- an institutionalized and participatory process for indicator selection;
- budgetary allocation for measurement;
- the appointment of an independent body to be officially responsible for measurement;
- bi-annual revisiting of the benchmarks and adjustment to changes;
- the use of time series and future projections; and
- reliance on urgent benchmarks.

Application at the Local Level

Local-level initiatives to define strategies to achieve sustainable development and to measure progress offer the richest choice for measurement and indicator projects. Communities, particularly municipalities were among the very first to initiate healthy city programs and, after the Rio Summit, local applications of Agenda 21. When international efforts to define sustainable development indicators were still stalled by debates on definitions, a few municipalities proceeded to define sets of sustainable development indicators and launched their measurement programs. These efforts are characterized by broad public participation and a clear focus on community well-being, but in most cases they lack coherent organizing principles in the selection and use of indicators. Their merit often is in the process of how they use measurement tools and indicators. There are many possible examples: Healthy City Toronto and Hamilton-Wentworth in Ontario, Whistler, British Columbia, Jacksonville, Florida, South Puget Sound and Seattle in Washington, Melbourne, Australia, and 10 pilot local authorities in the United Kingdom that participate in the country-wide Sustainability Indicators Project. Two have been selected: Seattle for its well-documented Sustainable Seattle program, and the Sustainability Indicators Project in the United Kingdom for its cohesiveness and well-documented pilot cases.

Sustainable Seattle

This initiative is a community-based project that was started in 1991 by the Task Team of Sustainable Seattle, a multi-stakeholder volunteer organization. The project puts emphasis on measurable dimensions of social life, economy and biophysical environment, and identifies indicators in a participatory process. One of the project's major strengths is a well-structured indicator selection process (Sustainable Seattle, 1995). There have been seven major steps to the process.

- Establish Task Team.
- Task Team develops draft set of indicators through four iterations.
- Civic panel of 150 established with representatives of key stakeholder groups.
- Civic panel reviews draft set of indicators, narrows the list and categorizes indicators into issue areas.
- Task Team conducts technical review of individual indicators.
- Indicator sets are further narrowed and focused based on data availability.
- Data are organized in a format appropriate for public distribution.

The other merit of the Seattle project is its concise presentation of indicators developed through a community participation process. An original set of 99 indicators in 10 topic areas were narrowed down to 40 measurable indicators in four categories (see Appendix A, Table A7). Each indicator has been presented with a description, definition, interpretation, evolution and linkages. At first, the indicators were grouped into two categories, the first 20 being well-researched parameters, while the rest were still under research and development. In 1995, a status report on the long-term cultural, economic and environmental health of the Seattle/King County area was published, using 40 indicators, roughly identical to the 1993 selection (Sustainable Seattle, 1993). The main categories for grouping the indicators have changed slightly, the five categories of classification being:

- environment
- population and resources
- economy
- youth and education
- health and community.

The indicators will be regularly updated based on feedback and criticism; some indicators will be added or deleted from the original list. While the structure of Seattle's indicator selection process is comparable to Oregon's, there are differences between the indicator sets resulting from unique local conditions, although they also make cross-regional comparison more difficult. There is some emphasis on institutionalizing indicator use, although it is less specific than in the case of the Oregon Benchmarks project. Indicators are to be disseminated and used for different purposes and by different audiences:

- in local media publications and broadcasting;
- in public policy fora, influencing policy makers;
- informing decision makers in business and development planning;
- assisting civil society to set its priorities;
- helping individual citizens change their personal lifestyle; and
- using as teaching tools in education.

Advantages: Indicators are identified in a multi-stakeholder process and presented in a concise format. A flexible structure is designed to be open for regular updates. The categories of classification reflect community priorities. While the indicators are designed to help decision makers, they are also good tools in education.

Limitations: Some selected indicators cannot be presented in time series, and comparisons over time will be difficult because of regular changes to the indicator set. The process does not emphasize target setting.

Relevance to Users: The Sustainable Seattle project offers:

- a participatory indicator selection process;
- a flexible structure for indicator classification;

- a concise set of indicators;
- the presentation of data to different target audiences; and
- the use of indicators in education.

United Kingdom — Sustainability Indicators Project

Within the United Kingdom, a project was initiated by the Local Government Management Board (LGMB) to develop indicators to measure local sustainable development and to place the community at the heart of the exercise. The project began in November 1993 with two phases.

The first phase included research into best practices, nationally and internationally, and development of a menu of indicators for testing. It also included the selection of pilot authorities and publication of an initial report with the menu of indicators and the guidance to pilot authorities.

The second phase was a six-month pilot project in which the 10 chosen authorities put theory into practice, evolving different ways of involving their communities, choosing indicators and publicizing the results.

The participants were Bedfordshire, Cardiff, Fife, Hertfordshire, Lancashire, Leicester, Mendip, Merton, Oldman and Strathclyde. The pilot was completed in February 1995 and a final report was published that year (LGMB, 1995).

There were several key issues for defining potential indicators for the pilot project.

- Relevance: Indicators must be appropriate to a local perspective, but should also be intelligible at a broader level.

- Existing reporting mechanisms: Although ease of measurement was not supposed to determine the chosen indicators, it was noted that many authorities had developed a wide range of methods for collecting and reporting on data which could be useful for wider purposes.

- Scale: An acceptable definition of “local” should be provided, as well as an explanation of how parameters of sustainability change accordingly.

- Political commitment and appropriate structures: Defining and implementing policy requires political commitment, as does encouraging community participation.

- Environmental carrying capacity: Incorporating the concept of environmental carrying capacity into work on sustainable development indicators is desirable in promoting wider debate.

Stakeholders' discussions centred on how to strike the right balance in translating "concerns," which might seem relatively parochial to practitioners, into "indicators" and how to link policies and indicators to local action. A framework for setting the suggested indicators in context was drawn up by the steering group. Components included:

- identification of working definitions of sustainable development;
- themes and key sustainability factors; and
- indicators.

The UNEP definition of sustainable development was used as the basic working definition of sustainable development: "Improving the quality of life while living within the carrying capacity of supporting ecosystems" (UNEP,1992). Carrying capacity covered the issues of resource use, pollution and waste, and biodiversity, while quality of life was taken to mean the meeting of human needs: basic needs (food, shelter, etc.), health, access to a range of facilities, meaningful work and so on. To make this clearer, a sustainable community was envisaged, with 13 components or themes (identified in Table 3).

Once the themes were identified, categorizing the indicators was relatively straightforward. A pool of several hundred indicator "candidates" existed: this was whittled down to 101 indicators by a voting procedure of the steering group. The final selection listed 146 indicators for the 13 themes, ranging from six to 16 for an individual theme. The work on developing indicators is continuing.

Though most communities believe that targets with dates for their achievement should be set if indicators are to realize their potential, they have approached target setting warily, for different reasons, such as lack of standards, lack of historical data for comparison, fear of being accountable for non-compliance, lack of early results, etc. Yet the pilots demonstrate that it is possible to involve communities in new ways of working toward sustainable development even if government is perceived as being self-interested in designing measurement structures.

Advantages: The indicator selection process reflects user priorities and is adjusted to local needs. Measurement relies on locally available data and reporting structures. It is designed with comparability in mind. Measuring progress is based on a political commitment to sustainable development, and developing indicators is a continuous process.

Limitations: The 13 reference themes are eclectically selected. The projects use too many indicators. Target setting has not been handled adequately, perhaps because the project was done under severe time constraints. It also lacked a harmonized definition of sustainable development as a reference point.

Table 3
Selected Themes for the U.K. Local Authority Pilot

#	Selected Themes	Detailed Description
1	Resources and waste	Resources are used efficiently and waste is minimized by closing cycles.
2	Pollution	Pollution is limited to levels which natural systems can cope with, and without damage.
3	Biodiversity	The diversity of nature is valued and protected.
4	Localness	Where possible, local needs are met locally.
5	Access to basic needs	Everyone has access to good food, water, shelter and fuel at reasonable cost.
6	Work	Everyone has the opportunity to undertake satisfying work in a diverse economy. The value of unpaid work is recognized, while payments for work are fair and fairly distributed.
7	Health	People's good health is protected by creating safe, clean, pleasant environments and health services which emphasize prevention of illness as well as proper care for the sick.
8	Access to facilities	Access to facilities, services, goods and other people is not achieved at the expense of the environment or limited to those with cars.
9	Crime	People live without fear of personal violence from crime or persecution because of their personal beliefs, race, gender or sexuality.
10	Access to skills and knowledge	Everyone has access to the skills, knowledge and information needed to enable them to play a full part in society.
11	Empowerment	All sections of the community are empowered to participate in decision making.
12	Culture and recreation	Opportunities for culture, leisure and recreation are readily available to all.
13	Aesthetics	Places, spaces and objects combine meaning and beauty with utility. Settlements are "human" in scale and form. Diversity and local distinctiveness are valued and protected.

Relevance to Users: The U.K. Sustainable Development Pilot offers:

- the use of available data and existing reporting structures;
- indicators developed in a continuous way;
- methods to mobilize and involve the public for support; and
- useful approaches to presenting indicators.

Private Sector Applications

There is a continuum of effort (and success) in the corporate world with respect to measurement issues. These can be described in four categories:

- legally required measurements;
- measurement of other emissions and aspects;
- broader sustainable development measurement; and
- full sustainable development measurement.

Legally required measurements include regulatory requirements for companies to measure various air and water emissions. Such data in the United States and Canada are published, with certain restrictions, by the regulators. One result has been to provide a common foundation of information across companies. Because of the regulatory basis of the measurement programs that produce the data, it is reasonably consistent and reliable from one company to another. From these data, it is possible to calculate measures of how well a company or a manufacturing site is complying with the regulations. How many times did actual emissions exceed the allowable level, and by how much? How much less are total emissions than the total allowable? Thus, while companies frequently set themselves "beyond compliance" goals, such goals often deal with the regulated substances, and success in reaching these goals can be measured in the relatively standardized fashion required by the regulations.

Some companies are measuring other emissions and aspects such as non-hazardous solid waste, packaging efficiencies and recycling, energy efficiency in production, etc. Such measurements, and any reporting that is done, are in the context of voluntary corporate goals. The methodologies used and the ways in which the data are kept and presented are decided by the company to meet its own information needs, so comparisons across companies are difficult, if not impossible.

A few companies are working to develop broader sustainable development measurements that will capture their economic, environmental and human impacts. Such experimentation, at its current state of development, tends to collect a variety of data together, in an effort to better understand all aspects of a product or plant's impacts on the environment, the people and community, and on its own financial situation. Often, the measurement and goal setting are put in terms of ongoing improvement, in the absence of specific targets.

The logical framework for full sustainable development measurement at the company level does not yet exist. Such a framework will require clear theoretical linkages to sustainable development measurement on a more global basis, such as links between the models discussed elsewhere in this paper and the sustainable development impact of the company. The example of the relationship between corporate financial accounting and national (or global) economic accounting is relevant here. Gross national income figures are basically aggregated from corporate financial reports, so it makes sense to say that General Motors makes up X% of the U.S. economy. Such a framework does not yet exist for sustainable development reporting.

As corporations (and other organizations) struggle with measuring their own progress, two barriers become apparent. The first is the lack of a theoretical framework that relates to the scale of the corporation and to global sustainable development. Without this, approaches are necessarily ad hoc, with little guidance as to important gaps in the measurement suite. The second and related barrier arises when companies try to aggregate their various financial, environmental and people-related data into summary statistics. They then must weigh the various data, and again there is no "objective" framework for doing so. A consensus approach to weighting, both within the company and with its stakeholders, is often the fall back. Of course, such a consensus is itself very hard to reach.

The issue at the foundation of any discussion about measuring corporate progress is that of goals. A company does not develop measurement systems and data unless it has a particular goal in mind and wants to manage its efforts to ensure that it reaches the goal. The corollary is that companies with differing goals will develop differing measurement systems, and consistency will not come about until consistent goals can be agreed upon.

Northern Telecom's Environmental Performance Index

Northern Telecom has developed a comprehensive index of its environmental performance (Northern Telecom, 1995). It combines a worldwide environmental data base with a calculation formula to produce a single, company-wide index, which can be used for goal setting and year-over-year performance analysis. The data base also supports corporate measurement of compliance with more specific goals relating to reducing pollution emissions, minimizing waste, resource conservation and energy efficiency.

- Developed in conjunction with A.D. Little Inc., the data base and performance index are based on site-by-site data collection. Each site in the company is required to complete a set of standard forms, which are spreadsheets that feed into a corporation-wide computer data base. The spreadsheets gather data on four sub-categories (Northern Telecom, 1995, p. 2).

- Compliance
  - notices of violation (total number)
  - fines (US$1,000)
  - exceedances (total number)
  - incidents (total number).

- Resource consumption
  - total energy consumption (MBTUs)
  - electricity (MBTUs)
  - water consumption (litres)
  - paper purchases (kilograms).

- Environmental releases (representing a total of 19 parameters)
  - air releases (kilograms)
  - water releases (kilograms)
  - land releases of solid and hazardous waste (kilograms)
  - releases affecting global environment (kilograms).

- Environmental remediation
  - number of remediation sites (number)
  - risk factor (number).

A key aspect of the Nortel index is that it is scaled to relate to the company's performance expectations, which are increasing over time. Thus, if actual performance is the same in one year as it was in the previous year, the performance index will fall, because the performance expectation has risen.

Each of the four major components mentioned above is weighted based on the perception in Nortel of its importance. Compliance is weighted at 25 percent, environmental releases at 50 percent, resource consumption at 12.5 percent and remediation at 12.5 percent of the total score.

At the conclusion of the calculations, Nortel has a single, company-wide index of its performance against that year's targets. A score of 175 means that all targets are fully met. In 1994, the company achieved a (revised) score of 136, and in 1995, a score of 140. This shows that Nortel is a bit closer to meeting its 1995 goals then it was to meeting the 1994 goals, despite the fact that the 1995 goals were more stringent.

Advantages: A single number index allows the company and its stakeholders to measure easily how well the company is meeting its goals. This index is based on data collected from each production unit of the company, on a consistent basis. It therefore will allow comparisons to be made between different units, though this is not currently done. The data base will also provide a foundation for other calculations of progress — whether through revisions to the index, through setting site-specific goals or other uses.

The Nortel index is performance oriented — it does not tell managers how to accomplish the goals, but measures actual results. Processes that efficiently help reach the goals will be rewarded with improved scores, but process itself is not scored. This allows managers to be creative in meeting the goals in the best ways they can devise. While the index does not integrate with Nortel's other performance measures, such as financial results, synergistic actions that result in positive impacts on both measurement areas will presumably be well regarded by management.

Limitations: This index suffers from the limitations of its type, in that it gathers disparate statistics together, and thus its meaning is difficult to explain to the casual user. For example, the index might show that Nortel made better progress in meeting its goals in 1995 than in 1994, but a careful examination of the goals themselves, and the weighting factors in the index formula, is necessary to determine whether the progress was important or trivial. Nortel makes the details of its methodology available on its Internet site, (http://www.nortel.com) in a highly commendable implementation of the principles of openness and transparency.

The Nortel index measures environmental performance, as defined by Nortel's environmental goals. It does not pretend to be an index of sustainable development progress.

Relevance to Users: For departments with substantial operational environmental impacts (as opposed to policy impacts), the Nortel model is excellent. The careful development process, with consultation across the company, highlights the need to ensure that local and corporate goals are consistent. The use of a complex calculation to produce a simple statistic is an excellent and practical example of the process. The methodology and approach can easily be extended to cover any topic where the department has set a numerical target. The process of establishing weights to attach to each topic or goal is essential for developing a shared understanding of priorities.

Eco Efficiency

The World Business Council for Sustainable Development (WBCSD) has developed the concept of eco efficiency. The WBCSD says:

> Sustainable development is a vision of economic activity that effectively manages the world's resources for sustained, equitable growth, worldwide. This vision can best be realized through market economies and economic incentives (Andraca and McCready, 1994, p. 20).
>
> The concept of eco-efficiency was further defined in the BCSD report, *Getting Eco-Efficient* as follows: "Eco-efficiency is reached by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle to a level at least in line with the Earth's estimated carrying capacity" (Andraca and McCready, 1994, p. 2).

Thus, eco efficiency is an approach to sustainable development that corporations can use to govern their actions and goal setting. It is based on the understanding that corporations can make money and improve environmental performance at the same time, thus improving overall sustainability. The eco efficiency approach contains four key elements.

- Providing service by meeting and exceeding customer expectations: This can help companies provide services to their customers that are as efficient as possible in terms of materials, environmental impact and so on.

- Focusing on peoples' needs: Because the ultimate customers are also the people of the world, it is important that their consumption needs be met in a sustainable way.

- Be environmentally responsible during all stages of a product's life cycle: A product's life cycle has four stages: raw material supply, manufacturing, use (and reuse) and disposal. An examination of these stages for their environmental impacts often reveals important and easily mitigated impacts that product producers have not considered. Redesign to reduce such impacts might bring substantial improvement, for a modest cost.

- Improve continually: This is a key goal for company management, in that it accepts that everything cannot be done at once, while committing the company to doing better every year.

One tool that the WBCSD suggests corporations use is to improve their accounting systems. This idea is developing in two directions: better allocation of existing costs and the recognition of "externalities" in decision making. Better cost accounting systems have been discussed at length in a recent World Resources Institute publication (Ditz et al., 1995). The case studies in *Green Ledgers* demonstrate that better understanding of existing cost structures can lead to much improved decision making about environmental issues in companies because large accounting systems often bury costs such as waste treatment, compliance costs, legal costs and so on, in a variety of shared or overhead categories. Thus, plan managers often do not know the real costs they are incurring in their product and process decision making. Better information leads to better decision making.

It is an interesting comment on the state of environmental management that the conceptually straightforward job of getting the existing cost accounting system to produce data in a more useful form should be such a challenge. To go beyond that to calculating the cost of various externalities is an even bigger step. Companies face questions such as: what is the environmental cost of one more ton of SO_2 emissions? The answer to this is inherently unknowable, because it involves knowledge of future impacts and the cumulative effects of this ton in addition to all others. Approximations however, can be calculated. While the WBCSD encourages this, it does not discuss specific methodologies or approaches.

Canada's National Round Table on the Environment and the Economy has recently published *Measuring Eco Efficiency in Business: Developing a Core Set* *of Eco Efficiency Indicators* (1997). The report discusses a possible set of indicators, in the areas of material and resource efficiency, product longevity and toxic releases. Work is continuing in this project.

Advantages: The eco efficiency approach puts the issues of sustainable development into the context of business operations and helps focus on the contributions that business can make. By focusing on customers, markets, products and corporate processes, eco efficiency helps businesses deal with sustainable development issues.

Limitations: Eco efficiency, at this stage of its development, is primarily a conceptual approach, one that brings together tools in a new way. Eco efficiency itself is not a measurement approach. Internal environmental cost accounting, accounting for externalities and life cycle analysis are all tools that can fit into the eco efficiency approach.

Relevance to Users: The approach was developed in an industrial environment and does not fully fit government departmental needs. However, the focus on customer needs, on meeting real market needs and on continuous improvement are all important in any organization.

Full Cost Accounting at Ontario Hydro

Ontario Hydro is developing and implementing a process of full cost accounting to aid its decision-making processes. It is defined as follows:

> Full Cost Accounting (FCA) is a means by which environmental considerations can be integrated into business decisions. FCA incorporates environmental and other internal costs, with external impacts and costs/benefits of Ontario Hydro's activities on the environment and on human health. In cases where the external impacts cannot be monetized, qualitative evaluations are used (Ontario Hydro, 1995).

The company has defined several key terms:

- Internal costs can be thought of as the costs Ontario Hydro incurs in doing business. However, in some corporations, including Ontario Hydro, there are often less tangible, hidden or indirect internal costs, including environmental costs, that are not identified separately or are misallocated to corporate or business unit overheads (e.g., contingent costs, community relations costs). If a business unit is not considering these costs, then the business may not understand the true costs of its products and services, and may, as a result, be making inappropriate business decisions.

- External impacts or externalities are effects on the environment and on human health that result from Ontario Hydro's activities, but are not included in the costs of its products and services. These impacts are therefore borne by society.

- Monetized external impacts are effects for which Ontario Hydro has developed monetary values. To date, Ontario Hydro has developed preliminary external cost estimates for the operation of its fossil stations and external cost estimates for fuel extraction through to decommissioning for its nuclear generating stations.

- Non-monetized external impacts are effects which can be described only qualitatively because there are scientific limitations in describing the full range of environmental and human health impacts. In other cases, the impact can be quantified (in physical units) but there are limitations in developing appropriate monetized values.

As discussed earlier, many companies have found that their internal cost accounting systems do not adequately allocate real environmental costs. Ontario Hydro has been estimating such costs since 1989 and is still defining its system.

Ontario Hydro estimates the dollar costs of some of the externalities it imposes on the environment. It uses the "damage function approach," which considers the effects each of its sites has on human health and environmental degradation. While such estimates are difficult and subject both to controversy and to wide variances, the result is a pioneering effort that can help guide corporate decision making.

The full cost numbers are not used to set prices, but rather to help make investment decisions. By quantifying (as far as the data and methodology allow) the environmental externalities of its investment options, Ontario Hydro can look for the best overall projects. The project data will also focus attention on synergy between environmental and economic components of project design criteria.

The data base for this analysis has been developed over many years: Ontario Hydro has been working to estimate the cost of externalities, using the damage function approach, since 1974. Projects that have an energy export component have been supported by environmental externality analysis at National Energy Board hearings for about 20 years.

Advantages: The Ontario Hydro approach is the best current example of a decision-making process that attempts to monetize most environmental costs. By using sophisticated analysis to bring most of the issues into a dollar-cost framework, it avoids the problems of comparing unlike quantities.

Limitations: While the methodologies used are subject to some conceptual debate, there is even more of a substantial debate about finding the right numbers. Estimates for costs of various items can vary widely. Even so, not all costs are captured, leaving some non-monetized issues to be dealt with.

Relevance to Users: The approaches developed by Ontario Hydro are relevant to any capital analysis. While Ontario Hydro has a relatively limited set of project types to analyze, the results can be used in other circumstances. Their experience in building up from simpler to more complex analysis, as data and methodologies become more developed, is also very relevant.

Experimental Sustainable Development Measurement Tools

The Ecological Footprint Model

The Ecological Footprint (EF) Model (Wackernagel and Rees, 1996) accounting tool that calculates the productive land area required to sustain resource consumption and waste assimilation requirements for a defined human population or economy. It is endorsed by many researchers and local initiatives. It measures the virtual amount of land an entity (person, city, nation) requires for the maintenance of its life, in a single aggregate index. For example, Rees calculates that Vancouver, through its food, water, energy and waste-disposal demands, actually occupies an area of land (an ecological footprint) 14 times the nominal area of the city. (Like similar material-flow-balance models the EF only considers the effects on the environment of economic decisions with regards to resource use).

Other calculations show that if all people on Earth had the same footprint as the average American (5 hectares), we would need three Earths to support everyone! The model calculates a "fair earthshare" (total productive land area divided by world population) of 1.5 hectares apiece, a number that goes down as the population grows. It points out that the average footprint of a citizen of India is just 0.5 hectares, but because there are 910 million Indians, the total footprint of India is 35 percent greater than the actual area of India. (The excess, says Rees, is supplied partly by imports and partly by drawing down the natural capital, mainly forest, of India.)

The ecological footprint is a function of population and per capita material consumption. The model assumes that all types of energy, material consumption and waste discharge require the productive or absorptive capacity of a finite area of land and water, and calculation of the model requires incorporation of relevant income, prevailing values, socio-cultural factors and technology for the area under study. The per capita footprint (ef) is the sum of the land appropriated for each purchased good (aa_i), which is calculated by dividing average consumption of each good (c_i) by the average productivity of each good (p_i). The population footprint can then be obtained by multiplying the per capita footprint (ef) by the population size (N).

$$\text{Ecological Footprint}\, P = N\left[ef = \sum\left(aai\right) = \sum\left(ci/pi\right)\right]$$

$$\text{where: } i = \text{purchased good (or input) } 1, \ldots, n$$

Because the assumptions of the model lead to overly optimistic estimates, the authors suggest multiplying present estimates by a significant "sustainability factor" to obtain more realistic results.

Advantages: The index is powerful, easy to understand and captures the logic of sustainable development. It is an excellent aggregate index that connects many issues of sustainability, development and equity. The model can reveal the extent to which local carrying capacity has been exceeded, indicates population dependence on trade, reveals the effect of differing income levels and technology on ecological impact and allows a cumulative approach to impact analysis. The use of land as a numeraire, rather than money or energy, makes the footprint easy to understand, and also permits provocative calculations.

Limitations: Its calculation scheme needs to be perfected and made dynamic so it reflects not only present footprints, but implications for future ones. This model does not include several important issues even directly related to land use: land areas lost to biological productivity because of contamination, erosion and urban "hardening" and possible ranges of consumption goods and waste flows. It only considers the effects of economic decisions with regard to resource use on the environment. The simplification in calculation methodology sometimes results in over-optimistic estimates.

Relevance to Users: The Ecological Footprint model:

- demonstrates the extent to which local carrying capacity has been exceeded;
- expresses resource use as a function of population and per capita material consumption;
- uses a single aggregate index to reflect the ecological impact of differing income levels and technology; and
- uses land as a numeraire.

The Barometer of Sustainability

The Barometer of Sustainability (Prescott-Allen, 1995) assesses a region's progress toward sustainability through the integration of economic, biophysical and social health indicators (see Figure 1). Development of the Barometer of Sustainability scale requires people to state explicitly their assumptions about human and ecosystem well-being so calculated sustainability ratings can be scored against desired levels. The Barometer of Sustainability is a combination of ecosystem and human well-being, each measured individually by its respective indices. Indicators for these indices are chosen only if it is possible to define them in numerical terms with regards to desirability, acceptability and unacceptability. This latter process allows the public to determine the level of sustainability it wants to achieve.

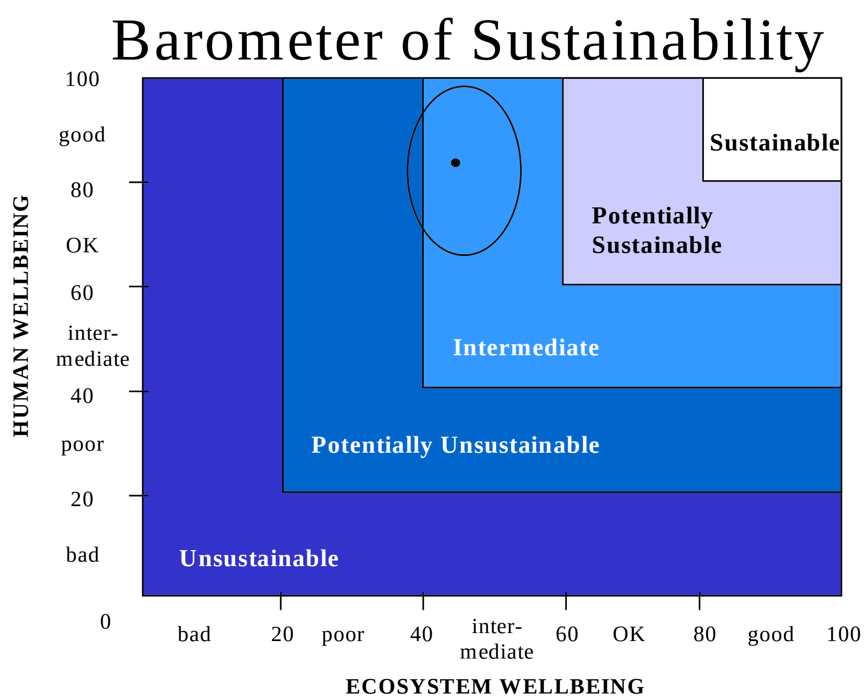
To compute progress toward sustainability, the values of the index of ecosystem well-being and the index of human well-being must first be calculated, as well as the sub-indices which make up these two indices. The index of ecosystem well-being identifies trends in ecosystem function over time. It is a function of land, water, air, biodiversity and resource use indicators. The index of human well-being represents the overall level of human well-being and is a function of the wellness of individuals: health, education, unemployment, poverty, earnings and crime on the one hand, and business and human actions on the other. (Detailed calculation of the indices is presented in Appendix B.)

Once the values of ecosystem and human well-being are obtained, they are plotted on their respective axis to present the rating on the Barometer of

Sustainability. The intersection point of these indices is a region's sustainability ranking and when sustainability ratings are compared over the years, the trend represents a region's progress (or lack of progress) in reaching sustainability. The Barometer of Sustainability can be computed for national as well as sub-national levels.

Advantages: The index captures the holistic character of sustainable development through the integration of ecosystem and human well-being into sustainability reporting. Ecosystem and human well-being index values are combined so information is not lost, i.e., an improvement in one index does not mask a decline in the other index. It offers excellent opportunities for presentation in map formats and comparative analysis.

Figure 1
Barometer of Sustainability



Note: The point represents the overall assessment of British Columbia's progress toward sustainability. The ellipse around the point represents the uncertainty with the calculations.
Source: Prescott-Allen (1995).

Limitations: Weighting of indicators is left to the discretion of the researcher and lacks scientifically shared criteria. However, the index incorporates the public's values into determination of sustainability. The calculation is complicated and can be made only if numerical target values or standards are available. The percentage scale is arbitrary and the uncertainty in calculation is quite great.

Relevance to Users: The Barometer of Sustainability:

- uses an integrated percentage scale for performance measurement;
- uses human well-being and ecosystem well-being indices;
- calculates methods for sub-indices; and
- provides comparative data presentation and mapping.

Genuine Progress Indicator

The shortcomings of gross domestic product as a measure of progress have long been known by economists and, to a lesser degree, by policy makers. The problem with the GDP is that it does not make any distinction between economic transactions that add to well-being and those that diminish it, and it ignores contributions which do not have market transactions, such as those of families, communities and the natural environment. As a result, the GDP often masks the breakdown of social structures and natural habitat and, in many cases, it portrays this breakdown as an economic gain. And yet economists, policy makers and the media continue to use the GDP as a primary score card for nations' economic health and well-being. Besides inertia, the continued reliance is often justified by the lack of a concrete alternative and the belief that it is extremely difficult to value social and environmental factors in economic terms. The Genuine Progress Indicator was developed to offer an alternative (Cobb et al., 1995). In a sense, the GDP calculation operates like a business income statement that adds expenses to income instead of subtracting them. For example, billions of dollars are spent annually on lawyers, security devices, and the like because of divorce and crime. The GPI tries to treat these as signs of social breakdown and a loss of well-being rather than additions to it. Likewise, clean-up activities because of polluted environments are included in the GDP but those who promote the GPI think they should be subtracted from the GDP to give a statement of net benefits.

The GPI seeks to develop estimates for the economic contributions of over 20 aspects of economic life that the GDP ignores. Then it integrates these factors into a composite measure so the benefits of economic activity could be weighed against the costs of such activity (see Table 4).

The GPI is a pilot measure of the well-being of the nation expressed in economic terms. It includes the values of both market and non-market activity within a single, comprehensive framework, and it has a long-term perspective that the GDP lacks. Where the GDP looks only at flows of expenditure in a given year, the GPI considers depletion of natural and social capital. Thus, it provides guidance as to whether current modes of economic activity can be sustained over the long term.

Similarly, the GPI adds up the value of services and products consumed in the economy — whether or not money changes hands. Then it subtracts three categories of expense related to that consumption:

- defensive expenditures (which compensate for past costs);
- social costs; and
- the depreciation of environmental assets and natural resources.

The GPI demonstrates how a broader accounting lens results in a very different picture of the U.S. economy. From the 1950s to the present, the GDP has grown steadily, suggesting that Americans have become progressively better off during that time. By contrast, per capita GPI grew by about the same rate through most of the 1950s and 1960s, but it has declined from the early 1970s to the present. In other words, a more inclusive measure suggests that the cost of GDP expansion — the current modes at least — have begun to exceed the benefits.

The authors do not claim absolute accuracy for their estimates for social and environmental factors. The nature of human well-being is too varied and subtle, and the economy affects it in too many ways for any single measure to be entirely satisfactory. They claim only that such factors as the breakdown of families and communities, and the depletion of natural resources have significant economic consequences. To assign a reasonable figure to these is more accurate than asserting, as the GDP implicitly does, that their economic consequence is zero.

Advantages: The GPI develops estimates for the economic contributions of over 20 aspects of the economic life that the GDP ignores. It integrates the factors into a composite measure so the benefits of economic activity can be weighed against the costs. It includes the values of both market and non-market activity within a single, comprehensive framework and provides a long-term perspective.

Limitations: The value of non-market products and services is very difficult to measure and needs a revised accounting system. The assignment of negative or positive value to a contributing factor is arbitrary and value-laden. The list of additional economic contributors is opportunistic and open for debate.

Table 4
Components of the Genuine Progress Indicator

Item	Adjustment in GDP
Personal consumption	positive
Income distribution	(adjusts consumption)
Value of household work and parenting	positive
Value of volunteer work	positive
Services of consumer durables	positive
Services of government capital	positive
Cost of crime	negative
Cost of family breakdown	negative
Loss of leisure time	negative
Cost of underemployment	negative
Cost of consumer durables	negative
Cost of commuting	negative
Cost of household pollution abatement	negative
Cost of automobile accidents	negative
Cost of water pollution	negative
Cost of air pollution	negative
Cost of noise pollution	negative
Loss of wetlands	negative
Loss of farmland	negative
Depletion of non-renewable energy resources	negative
Other long-term environmental damage	negative
Cost of ozone depletion	negative
Loss of old growth forests	negative
Net capital investment	positive/or negative
Net foreign lending or borrowing	positive/or negative

Source: Cobb et al. (1995).

Relevance to Users: The Genuine Progress Indicator offers:

- revised calculation of the GDP;
- monetized non-market services such as family work and volunteer activities; and
- improved income/expense sheets and calculations to assess true costs of environmental and social degradation.

Human Development Index

In its 1990 Human Development Report, the UNDP developed the human development index (HDI) to rank a country's performance on the criteria of human development, instead of economic performance reported by the GNP or GDP. Though the index has not been developed as a sustainable development index (consequently environmental conditions are addressed only indirectly in that deteriorating environmental quality over time will have negative impacts on life expectancy), recent efforts have been made to supplement it with an environmental dimension to better reflect a whole system approach.

The HDI is a function of three components deemed necessary for human development, regardless of spatial and temporal factors: educational attainment (measured by adult literacy and mean years of schooling), longevity (measured by life expectancy) and standard of living (measured by purchasing power which is derived from GDP per capita and income above the poverty line) (UNDP, 1996). The three components of HDI are given equal weighting because they are assumed to be equally important to human development. The index is calculated on a national scale, but can also be adjusted to address sub-national scales. Detailed calculation of the index is presented in Appendix C.

Advantages: The HDI uses easily obtained data and focuses on trends in human development instead of economic performance as an overall ranking of a country's welfare. It's easy to calculate, and uses a simple method for comparisons. Since the development of the original HDI in 1990, the UNDP has modified the model to include years of schooling and income above the poverty line for the education and income indicators. The HDI can now be applied to different groups within the population by adjusting it for income distribution, gender disparity, geographical location and ethnicity so disparities within a population will not be lost in the national HDI average (UNDP, 1994).

Limitations: The main limitation of the index is the arbitrary, ad hoc selection of components to determine human development. There is little inherent connection among the components, and even that depends on the cultural setting. Averaging the three-component indicators for a nation can conceal important trends within the population. There are some concerns with the original HDI: the impact of infant and under 5 years of age mortality rates may mask changes in adult mortality rates that run counter to the trend in child mortality, and literacy may present a misleading picture of educational attainment in a country.

Relevance to Users: The human development index uses:

- three aggregate indicators to measure social and economic trends;

- the HDI as a summary component of social trend analysis; and
- the method for calculating disparities among different group(s).

CHAPTER 4: CLASSIFICATION OF MEASUREMENT APPROACHES, CONCEPTUAL FRAMEWORKS, AND METHODOLOGICAL ISSUES

A variety of sustainable development measurement examples were presented in Chapter 3. The grouping of these examples followed a simple method of classification: the level of activities based on jurisdictional borders has been divided into international, national, sub-national and local levels. While this is a very practical approach and the easiest way to present an illustrative survey, it does not help distinguish the differences in establishing and applying measurement frameworks and indicator sets. A more systematic analysis of the examples is needed.

Classification of Measurement Approaches

As in every survey, classification emerges as an important task to help orient an interested audience that wants to make good use of the many examples offered. Classification also helps in identifying the scope and limits of our current knowledge and in reviewing the available methods. The real significance of classification is that it does more than group different methods and measurement projects for convenience: it helps select the most adequate format and methods of measurement. Classification is based on common features of the individual examples; there are always, however, more than one set of common characteristics, so there is more than one way to classify measurement and indicator projects.

Classification by Scope

This type of classification is based on the issues measured, in other words, on the issues governments, businesses or experts deem important. The most common classification refers to measurable media such as the biophysical, the economic and the social/human media.

- Biophysical measures include information on the conditions of and changes in renewable resources such as land and soils; atmosphere, including climate and air quality; water quality and quantity; wildlife and vegetation; conservation lands and natural habitats; and non-renewable resources such as minerals and metals and fossil fuels.

- Economic measures include information on the conditions and changes in production, trade and services (usually in sectoral analysis); fiscal and monetary data (banking and finance, inflation, balance of trade, budget); and human resources (employment, labour and income).

- Social/human measures include information on the conditions and changes of demographics; public health; recreation and leisure; education; housing; infrastructure and social services; community development; public safety; the native/indigenous community situation; personal satisfaction; and archaeological and historical resources.

An alternative classification by scope could group indicators within the framework of quality of life. In this case, measurement covers four main areas:

- wealth (economic well-being);
- health (physical well-being);
- culture (mental/intellectual well-being); and
- politics (civil rights, safety).

Classification by Spatial Framework

Measurement initiatives can be classified based on the spatial unit they apply to:

- spatial units with geographic boundaries (global, continental, regional, local);
- administrative-political units (countries or group of countries, states, provinces, municipalities, rural regions, small communities);
- ecosystems (natural units of identical ecosystems, e.g., watersheds, arid and semi-arid areas, deserts, mountain areas, rain forests).

The most widespread spatial framework is the one based on administrative/jurisdictional boundaries, partly because the main sources of data are statistical offices tied to the political structure and jurisdictional units, and partly because the other main source of data, biophysical monitoring systems, also operate within administrative structures. Geographic and ecosystem boundaries are often coincidental, while the boundaries of administrative units usually disregard the others.

Classification by Applied Frameworks

In any measurement project, one of the first tasks is the definition of a framework in order to focus and clarify what to measure and what to expect from measurement. The framework is the most direct reference to the underlying concepts of sustainable development that define the assessment process. For this reason, the most important conceptual frameworks will be surveyed in a separate section.

Frameworks

A framework is a conceptual model that helps select and organize the issues that will define what should be measured by indicators. Conceptual models, even without truly capturing the real world, the complexity of which is beyond current knowledge, also provide a mechanism against which the real world can be set to facilitate learning. This comparison often leads to constructive tension, debate and, eventually, to the accommodation of different interests and values. The sought-after result is improved decision making.

The main differences among frameworks are:

– the ways and means by which they identify measurable dimensions, and select and group the issues to be measured; and
– the concepts by which they justify the identification and selection procedure.

Five models currently influencing measurement of progress toward sustainable development will be reviewed. The term “model” is used to generalize the common conceptual structure of similar frameworks that are used in practical projects. These models have been selected on the basis of the practical examples presented earlier and include a reference to the reviewed examples that can be identified with the respective model. The models may be categorized as economics-based, theme, stress-response, linked human and ecosystem, or multiple capital models. A brief summary of each follows.

Economics-Based Models

These models dominate contemporary thinking. They reflect input–output models and have evolved through three stages.

- A conventional circular model matches the flow of goods and services (plus wages and interest) from firms with household consumption (plus savings) (e.g., see Jacobs, 1993).

- The materials and energy balance models of the 1970s which hold material and energy content of inputs from the environment constant through production and use of goods through to discharge of waste to the environment (e.g., see Kneese et al., 1970; Freeman et al., 1973). This type of model was developed to overcome three criticisms of the conventional model, namely that it ignored all energy and material flows, the basic laws of physics governing these flows and the backward linkages of resources to ecosystem structure or function.

- The currently dominant depletion–pollution model links the circular economic system, consisting of production by firms and consumption by households (and regulation by government) to the natural life support system (including air, water, wildlife, energy, raw materials and other environmental amenities) through the "extraction" of resources in one direction and the discharge of "residuals" in the other (e.g., see Tietenberg, 1992).

Several examples illustrate these models. The Genuine Progress Indicator represents the conventional circular models. The conceptual framework proposed by the Netherlands' National Institute of Public Health and Environmental Protection for organizing UNEP's reporting function reflects the depletion–pollution model (RIVM, in preparation, as quoted in UNEP and DP CSD, 1995). Similarly it provides the underpinnings to the calculation of the Ecological Footprint. A good example for the materials and energy balance model is the material input per service unit (MIPS) framework, developed by the Wuppertal Institute for Climate, Environment and Energy in Germany, and the sustainable process index (SPI) developed by the Institute of Chemical Engineering at the Graz University of Technology in Austria.

The efforts to amend the System of National Accounts (SNA) also belong to this group of models. These initiatives have been under way for several decades; leading agencies to implement reform of the SNA include the UN Statistical Division, EuroStat Office of the European Union, the Norwegian Bureau of Statistics and Statistics Canada.

The Three-Component or Theme Models

These models are dominant in the sustainable development literature. The three components include social, economic and environmental fields. There are many variations and inconsistencies in what is included in each of the three. For example, the social element may address some or all of social, cultural, community, health or equity concerns. The environment element may refer to narrowly defined environmental or physico-chemical concerns or, in more general terms, concerns related to ecology, natural resources and environmental development. The economic element addresses traditional economic issues, wealth generation or physical prosperity.

Theme-based models are endorsed by many community-based sustainable development initiatives, including the government of the Netherlands. These models are not based on a coherent conceptual framework (except the policy performance indicators of the Netherlands) but compile a suite of indicators that reflects the concerns of communities regarding different issues (themes). Best examples include projects like the Alberta sustainability index, the Oregon Benchmarks initiatives, Sustainable Seattle and the U.K. local authority pilots.

Stress and Stress–Response Models

Early versions of these widely applied models focused on stress imposed by the environment on people (for example see Janis, 1954 who examined disasters or Wolpert, 1966 who investigated migration as an adjustment to environmental stress). However, the current stress–response models stem from work by Rapport and Friend (1979) aimed at organizing environmental statistics. Their framework included four categories:

- the stressor of activities;
- environmental stress;
- environmental response; and
- collective and individual human responses.

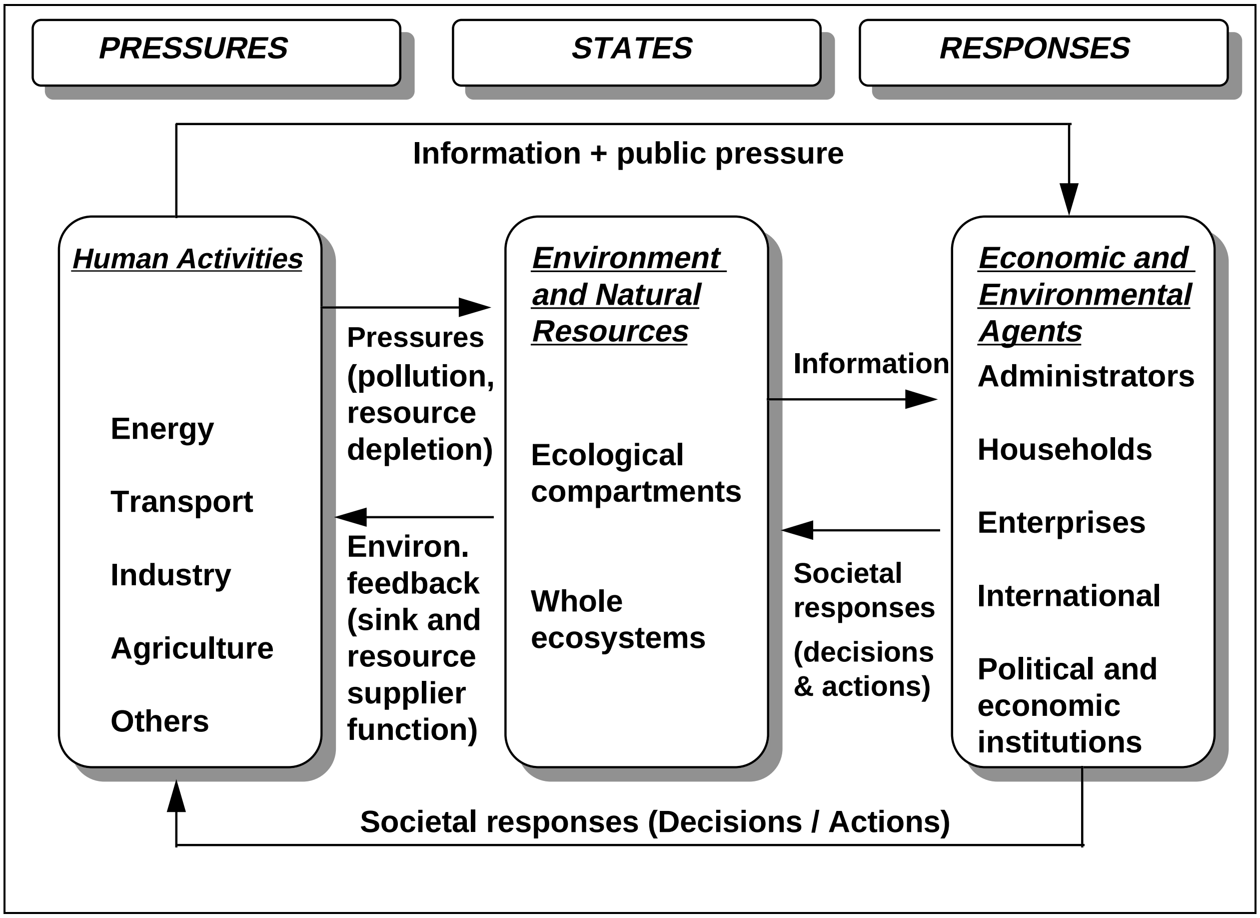
This model is not based on the economic activity-driven input–output models. The key novelty was the recognition that stress imposed by human activity spans physical, chemical and biological attributes, and is not limited to pollution. This is the origin of the OECD's pressure–state–response model (OECD, 1993) and the more recently developed driving force–state–response version of the UN CSD. Statistics Canada's population-environment-process model (Hamilton, 1991) is a hybrid that combines some aspects of the stress–response developed by Rapport and Friend with the pollution–depletion model described above.

Based on a perceived causal relationship between stress-generating human activities and changes in the state of the natural and social environment, the model presumes that, with adequate responses, the impacts can be mitigated and/or prevented (See Figure 2).

Many measurement and indicator projects, at least in their design, apply some variation of the pressure–state–response model, including the European

Union's environmental pressure index, the national indicator set of Canada, the theme indicators of the Netherlands and the Sustainable Development Indicators of the U.S. President's Council on Sustainable Development.

Figure 2
General Framework of a Pressure–State–Response Model



Source: O'Connor (1994) modified by Hardi and Pinter (1995).

The Linked Human/Ecosystem Well-Being Model

This model was developed to apply systems ideas to the goal of maintaining or improving human and ecosystem well-being together (Hodge, 1995; NRTEE, 1993). Four indicator/assessment domains are identified, including:

– ecosystem (indicators facilitating an assessment of ecosystem well-being;

– interactions (indicators facilitating an assessment of the flow of benefits and stresses generated at the interface between people and the enveloping ecosystem);
– people (indicators facilitating an assessment of human well-being; and synthesis (indicators facilitating an assessment of emergent system properties and providing an integrated perspective for current and anticipatory analysis).

The prototype of these models is the approach of Canada's NRTEE. For more details on the model, see Chapter 3.

The Barometer of Sustainability is another example of the application of the linked human/ecosystem model.

Multiple Capital Models

Sustainable development translates into providing future generations with as much, if not more, economic, environmental and social capital per capita as we have had ourselves. We accept that the composition of the capital we leave for the next generation will be different (in terms of its constituent parts) than the capital we have used during our lifetime. Capitals are usually divided into four categories: human-made capital, natural capital, human capital and social capital. These dimensions of capitals are considered endowments that should be preserved, enriched or substituted if consumed.

Natural capital is basically our natural endowment, and is defined as the stock of environmental assets (such as soil, atmosphere, forests, water, wetlands), which provide a flow of useful goods or services. The flow of these goods and services from natural capital can be renewable or non-renewable, and marketed or non-marketed. Sustainability means maintaining environmental assets, or at least not depleting them beyond some limits. According to this interpretation, any consumption based on the depletion of natural capital should not be counted as income, it must be a reduction of natural capital. Unfortunately, most economic analysis today does not make such adjustments and tends to treat consumption of natural capital as income. Unless such adjustments are introduced, there is continuing risk that such analyses promote patterns of economic activity that are inherently unsustainable.

Human-made capital includes all produced assets generally measured in financial and economic accounts. Specifically, it includes fixed assets, infrastructure (both inherited and newly created) and financial assets and stocks.

Human capital includes investment in health, education and nutrition. In the last three decades, considerable progress has been made in recognizing the importance of human capital formation. Investment in people is now seen to be a very high return investment, especially in developing societies. The entire mainstream paradigm of development has expanded to include investment in human resources as an essential ingredient of development strategy. Nevertheless, there are still difficulties in defining the monetary value of such investments. It is encouraging that even the most conservative measures show an overwhelming positive return on such investments.

Social capital refers to a degree of common identification with the forms of governance and of cultural expression and social behaviour that make a society more than the sum of a collection of individuals. Without social capital, it is impossible to imagine a functioning social order. The myriad institutions that we take for granted as the essential premise of a functioning society must be grounded in a common sense of belonging by the members of a society. The institutions must reflect a sense of legitimacy in their mediation of conflicts and competing claims. In short, if that social capital is not there, the resulting failures make it difficult to talk of economic growth, environmental sustainability or human well-being.

Social capital is based on inclusion, participation and the promotion of an enabling environment. Yet it is more. The most ambitious work to date on this subject has been the effort to deal empirically with the link between good governance and development. This requires definition and measurement efforts which face quite formidable methodological obstacles.

Wealth estimates suggest one more approach to measuring social capital. Rather than taking human capital as a residual, this form of wealth could perhaps be approximated by considering the main items that add to the value of the individual, notably education, health and nutrition. If so, the same residual logic that has been applied by the World Bank to measuring human resources could be shifted to social capital. Thus, social capital would be measured by deducting the value of produced assets, natural capital *and* human resources from the discounted future income stream of today's population (World Bank, 1995, 1996).

The best application of such a model is presented in the four capitals approach of the World Bank. The approach of the U.S. President's Council on Sustainable Development's Inter-Agency Working Group on Sustainable Development Indicators partially applies this model. Manitoba's pilot reporting on sustainable development in the prairie ecozone also classifies issues of measurement using the four capitals approach.

Comparison of the Models

Conceptual models provide a mechanism for comparisons with the real world to facilitate learning. However, the models themselves should not be thought of as truly capturing the real world, the complexity of which is beyond current knowledge. To do so can lead to the entrenchment of current perceptions along with all their limitations.

The usefulness of an effective framework lies not only in its facilitation of indicator selection, but also in its capacity to highlight indicators that do not reflect current priorities but might emerge as important in the future. Knowing what is *not* being emphasized is as important as knowing what is. In an analogous way, a lack of data for some indicators is an important signal. Thus, the effective framework serves as a template to be revisited from time to time in a test of current priorities.

While the models seem to differ significantly, often the differences are only in the terminology, describing essentially similar approaches. In other cases, the differences arise because of a focus on one or another aspect of the same issue. For example, the three-component or theme models do not significantly differ from the multiple capital models: each tries to capture the complexities of the ecological, economic and social dimensions, though from different perspectives, by different measuring units and different emphasis on the social dimensions. Similarly, these dimensions are the focus of the linked human/ecosystem model, differing not so much in the scope of the measured dimensions but in the emphasis on the linkages among the component dimensions.

In the variety of real life applications, a colourful palette of indicators reflects a less rigorous and rigid approach to assessment. Pressure–state–response considerations are mixed with theme classifications; themes are combined with capital-centred models, etc. Often, the models are not exclusive and can be applied together. For example, the selection of the measurable issues can follow a multiple capital method, while indicators can be defined within the issues according to pressures, conditions and responses.

This survey offers a template from which those who wish to implement a sustainable development performance measurement project can choose. It does not promote any single approach as the best one. Empirical evidence supports the need for using different approaches for different purposes as well as the use of hybrid frameworks. The main limitation in such an application is the difficulty in comparing outcomes. The measures to be used in comparative analyses should be based on identical or at least compatible frameworks and methods.

Clarifying Methodological Issues

Even in an ideal case of complete agreement on definition and interpretation of sustainable development concepts or the use of a framework, there are methodological issues, including procedural and institutional ones, that confront measurement projects.

The use of indicators raises two separate but linked issues.

- Aggregation of data: This refers to the question of how to aggregate variables expressed in different units of measurement (e.g., different physical entities, or in more complicated cases, physical and social entities) or presented in different time series and referring to different spatial units. In principle, aggregation is not a mathematical average of combined data but a weighted average of individual data. Weighting, however, is a value judgment, attributing higher importance to certain data than to others. The principles of weighting need to be properly justified.

- Creation of composite indices: Creating measurement techniques for simple characterization of policies and activities, using as few indicators as possible, is an operational problem. Composite indices are necessary because of the integrative perspective of sustainable development. The problem of these indices is that the combination of data is frequently arbitrary.

Aggregation and the use of composite indices are important in order to make valid judgments on and/or comparisons among major trends of sustainable development policies.

Methodological issues can be interpreted in a more general way, extending the notion to all technical conditions that influence the measurement process. In that sense, the procedures and the institutional settings of measurement also raise important issues.

The most pressing procedural issues that a measurement project must clarify are:

- the need for an independent information data base for cross-country, time series comparisons;
- the need for extended monitoring capabilities to collect and verify data; and
- setting clear standards against which policies can be evaluated.

Some of the most important institutional issues are:

- securing the independence (reliability) of data-collecting institutions;
- securing the availability and dissemination of data and a feedback process;
- establishing global networks; and
- creating funds to cover the costs of measurement and data processing.

Yet some of the greatest difficulties a measurement project faces are not what and how to measure but how to interpret measured data and judge the significance of the particular information. Some measurement projects simply provide an inventory of indicators without using them to link policies and actions to outcomes. The interpretation of measures are affected both by the frameworks and the methods, but the ultimate result will depend on how the measurement process is applied in decision making.

Brief Evaluation

The survey of practical applications in Chapter 3, and the conceptual frameworks and methodological issues of sustainable development measurement, presented in this chapter, demonstrate significant achievements in measuring sustainable development during a brief period of time. They also highlight the limitations and difficulties present and future projects have to face.

Achievements to Date

- Active existence: An increasing number of international agencies, governments, local authorities and private sector businesses have launched sustainable development measurement programs. These programs may help in moving from principles and statements to practical strategies and in bringing the ecological and sustainability factors into everyday decision-making practices in all walks of life.

- Defining objectives and targets: Decision makers, both political and business, want to know how far and how fast a society or an enterprise can go in depleting its natural capital and how much environmental quality or social equity is needed and wanted. Measurement programs help set goals and strategies that are complementary to previous goals to maintain economic capital and avoid serious indebtedness and deficits. They have contributed to the formulation of better standards.

- Empirical and quantitative basis for evaluation: While previous performance reports have often lacked clear empirical foundations and have been predominantly qualitative, sustainable development indicators help inform decision makers on how well or how poorly they are doing in achieving a stated goal; measurement helps evaluate the results of actions and their impact on the objectives.

- Choices and corrections: Measurement provides evidence and empirical support for making policy choices and corrections. Based on empirical evidence, decision makers improve their capability to choose, from competing alternatives, the one which best meets the goals of sustainable development.

- Comparison: Indicators have been used to identify trends over time, to allow comparisons between past and present trends, and among different regions. They allow the comparison of current conditions with desired performance, and help judge the sustainability of present practices.

- Reflecting constraints: Measurement has played a role in the identification of thresholds beyond which both human and natural habitats undergo irreversible change. In some cases, indicators help diagnose unsustainable trends, but more often they help identify trends that may lead to unsustainable outcomes.

While measures of sustainable development might have many useful aspects, there are several problems, both conceptual and practical, that are related to the tools and process of measurement. They should be kept in mind in designing measurement programs.

Conceptual Challenges

There are numerous conceptual problems of measurement that science cannot adequately solve. These affect interpretation of sustainable development as well as the methodological issues of what and how to measure. The most important challenges are the following.

- Scientific approach: Through the last several centuries, the dominant scientific method has been to examine discrete system elements thoroughly at the expense of understanding the whole system. Throughout this period, disciplines have evolved as separate cultures. Bridging these disciplines is difficult but necessary to achieve an integrated perspective.

- Cause–effect linkages: The linkages between wealth-generating human activity and stress on people and the ecosystem, and the resulting human and ecological conditions are often imperfectly understood.

- Definition of indicators: One of the main issues of measurement is whether an indicator should be a quantitative or a qualitative figure, and an ordinal expression of a stage to make comparison possible. It is a problem which has sidetracked most international efforts to establish measurement regimes even after the Rio Summit. Technical data might be well measured while trends, especially social, ideological and value trends might not and, as a consequence, factors being measured might be of much less significance than the ones which are hard or impossible to measure.

Methodological Limitations

- Data availability: The availability of data is uneven across programs and locations. Most data-collecting methods, statistical and monitoring systems alike, were designed at a time when sustainable development was not considered a policy issue.

- Analytic techniques: Most are far from adequate, particularly when dealing with cumulative impacts over time.

- Compatibility of data: In principle, even if most sustainable development issues can be quantified, they cannot be directly compared. For example, losses in biodiversity cannot be compared with economic gains or losses if they do not have a price attached to them. Without compatible dimensions, aggregation and broader comparison will continue to be a problem.

- Resource limitations: There are very real limitations to human, financial and time resources for effective measurement. Most constituencies interested in sustainable development measurement lack adequate human and financial resources to run measurement programs, and they don't have the luxury of stopping the world and waiting for a full understanding.

Some of these problems and limitations will be addressed by new and redesigned measurement programs; many will continue to influence the success of sustainable development measurement efforts.

CHAPTER 5: APPLICATION OF MEASUREMENT TOOLS

Measurement and indicators are useful tools to assist decision makers and can be applied for policy development (the planning function) and policy control (the assessment function), as discussed in Chapter 2. There are four other functions of measurement that help policy making and implementation:

- Analytical function: Measurement helps interpret data within a coherent framework and groups them into a matrix for indicators. Both the framework and the matrix will be based on the availability of data and analytical methods, and will focus on the policy assessments of decision makers.

- Communication function: Measurement makes decision makers familiar with the concepts and methods of sustainable development evaluation, and helps plan future developments and set up co-ordinating mechanisms both for evaluation and feedback analysis. Indicators help both with setting goals and with measuring success in reaching them.

- Warning and mobilization function: Measurement helps administrators put mechanisms in place for major periodic (multi-year) assessments, time series analysis and indicator updates. These mechanisms should include the annual publication of a simple report card with key indicators.

- Co-ordination function: A measuring and reporting system should integrate data from different issue areas and data collected by dispersed agencies. It should be handled cost effectively both in budgetary and human resource terms, and be open for public participation and control.

These functions are best revealed in the process of indicator selection and in the implementation stage when decision makers use the measurement tools and indicators. The following section reviews these two stages of the processes in which indicators are applied.

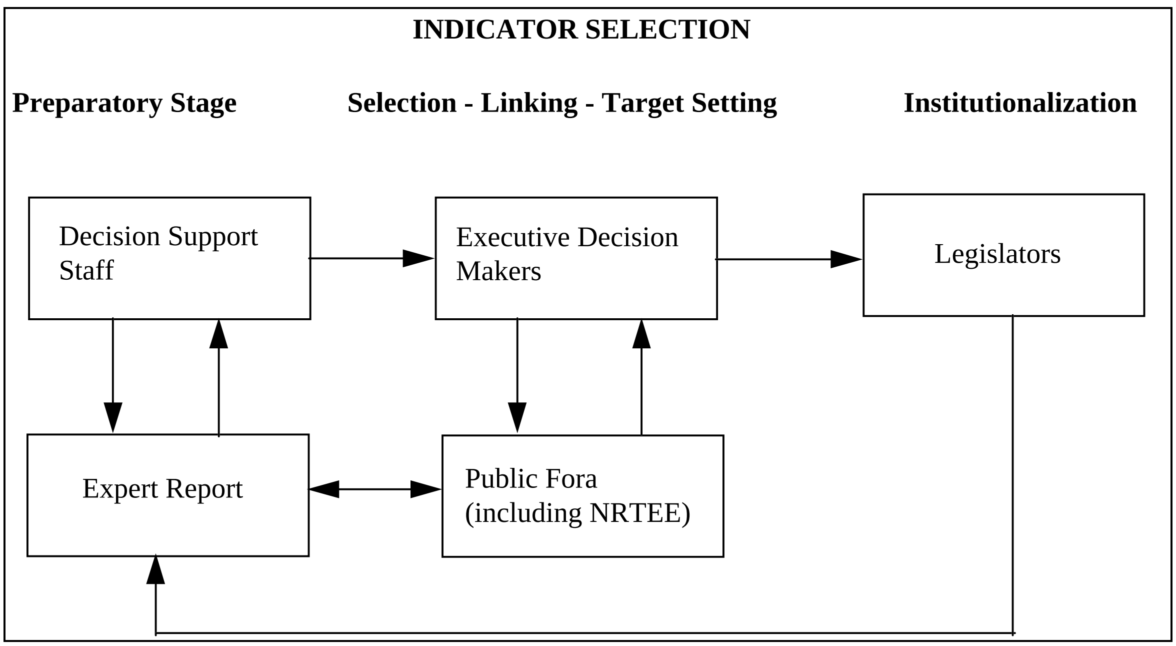
Indicator Selection Process

Indicator categories and individual indicators are usually identified and validated through a focused exercise either using a public hearing or consultation process or working with representatives of major stakeholders from government, non-governmental organizations, the private sector, academia and the general public.

Indicator selection should proceed in three main stages (Figure 3). In the preparatory stage, participants include experts and decision support staff who focus on the following issues:

- preparation of an expert report on project structure and strategies;
- assignment of project management responsibilities;
- preparation of the project plan;
- identification of indicator selection criteria; and
- selection of issue areas and a preliminary list of indicators.

Figure 3
Indicator Selection Process Structure



Source: Hardi and Pinter (1995).

The preparatory stage of indicator selection is primarily expert driven. Although public participation and stakeholder involvement in the later stages will have the power to modify the list, experts should have considerable impact by recommending issue areas and core indicators as well as the methodology for using indicators.

Given the differences in interpretations of sustainable development and the preferences of various stakeholders, a consensus should be achieved on the most crucial issues that affect sustainable development of the respective community, whether its as small as a town or as large as a nation. This would lead to a set of prioritized, optimal indicators that reflect the stakeholders' views as a whole. The next task is to set targets and time lines, corresponding to the applicable vision of sustainable development.

The third stage of the indicator selection process is institutionalization, where the indicator set, the mechanism for its periodic review and the associated target values are endorsed, and necessary human and capital resources are allocated and approved by legislative authorities. Provision should be made to assign the responsibility of data collection and monitoring to specific agencies and the task of central information gathering, indicator reporting and overall project co-ordination to a single organization.

Public participation has been referred to as a method recommended for the identification of sustainable development indicator sets. Besides being a method, however, public participation is also an indicator itself, measured and reported by various projects.

An important issue in the selection process is that of who selects indicators and how. Two approaches dominate the field.

- With the top-down approach, experts and researchers define both the framework and the set of indicators to be applied by different audiences and decision makers who may modify them to fit local characteristics but have no major say in defining them. Many international efforts such as the design of the UN CSD's indicator set and national measurement programs are typical of the top-down approach. The expectation is that these pre-defined measurement tools and indicator sets should be used across the board, in sub-national units, such as states or provinces, as well as in municipalities and local authorities.

  The advantage is that this approach provides a conceptually more homogenous, scientifically more valid set of indicators; it may include measurement of irreversible processes and threshold values. Its limitation is that it has no direct relation with communities; it lacks a sense of community priorities and does not consider resource limitations.

- With the bottom-up approach, measurement themes and indicator sets are proposed in a participatory process that is initiated by community opinion leaders and decision makers, and then finalized by consulting experts. Most sub-national level measurement initiatives are characterized by this approach, particularly those designed in municipalities and local communities.

The advantage of this approach is that community "buy-in" is secured, and priorities as well as resource scarcities are clearly reflected. The limitation of the approach is that it might be narrowly focused and could miss issues important for sustainable development.

The optimal situation is one in which communities select priority issues in a multi-stakeholder, participatory process and incorporate them in a framework developed by experts. Some of the most promising measurement initiatives, such as the Canadian NRTEE approach or British Columbia's report on progress toward sustainable development, prove the viability of such a method

Application in Decision Making and Reporting

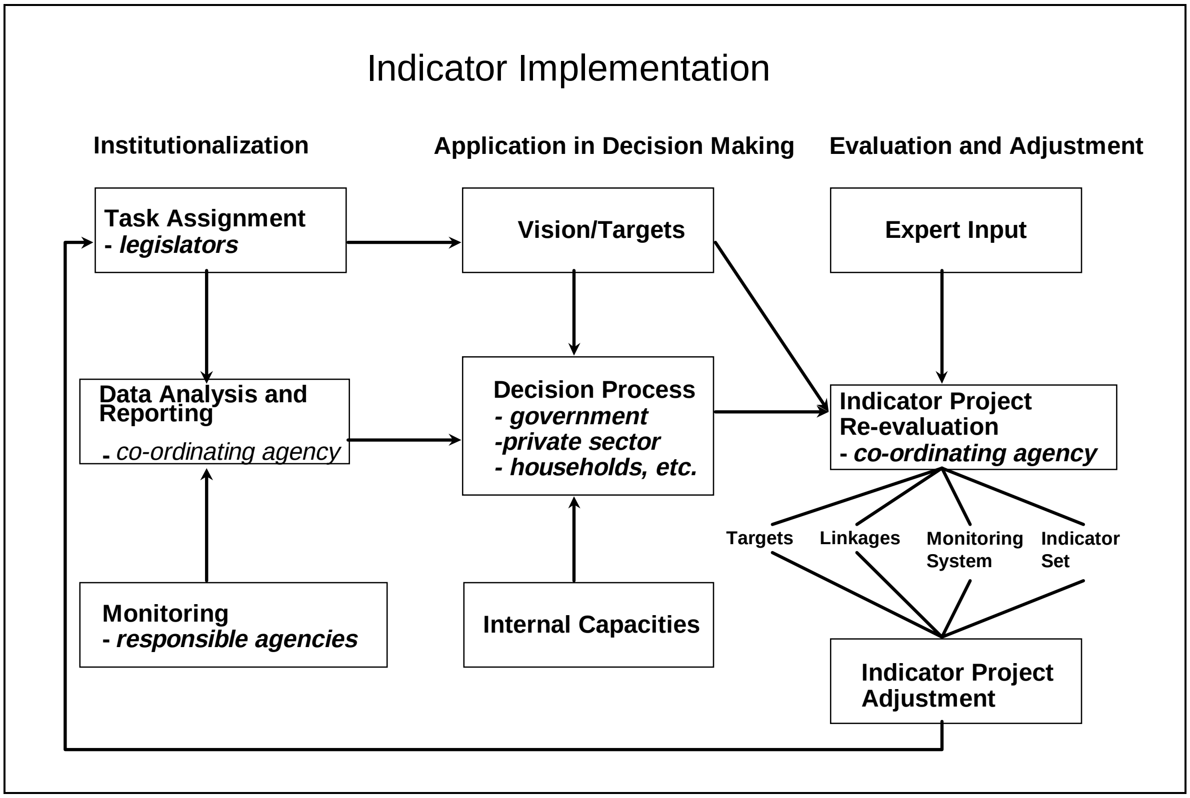
A general scheme of the implementation of measurement projects and the application of indicators is shown in Figure 4. The first phase is the institutionalization stage when monitoring, data analysis and the reporting system are put in place. In the second phase, decision makers consider actual and target values of indicators and make choices among alternatives.

In the third phase, periodic reviews are to be undertaken by the co-ordinating agency on the advice of indicator users and independent experts, and by considering the actual progress measured by each indicator. Revision should be extended to targets, major linkages among indicators, the actual indicator set (redundancies or additions) and required adaptations of the monitoring process.

As local socio-economic and biophysical conditions and value systems are diverse, so also are the goals and indicators of sustainable development. These differences seem to support the concept of sustainable development being a "story line," requiring contextual interpretation.

There seem to be similarities among projects under different conditions on two accounts. First, although indicator sets are never completely overlapping, there are strong scientific arguments for a category of compulsory biophysical indicators as a minimum requirement of sustainability. The argument is that approaching sustainability in the social or economic sense is strictly conditional on a number of critical factors. It is debatable to what extent the expert-derived minimum indicator set should come under stakeholder scrutiny. Second, there are similarities in the way indicator selection procedures are structured. There is also an emerging consensus on a framework for the identification, use and organization of indicators, which is conducive to the recognition of cause-and-effect relationships and harmonization of human activities and environmental as well as social conditions.

Figure 4
Process and Participants of Indicator Implementation



Source: Hardi and Pinter (1995).

Management Systems and Measuring Sustainable Development Performance

Environmental and sustainable development management cannot be treated as separate from other management functions. The overall goals of any organization in these areas must be set in conjunction with all its other goals to avoid inconsistency or conflict among the accepted goals which would make their achievement unlikely or impossible. But there is a further, and even more important reason — efficiency. When planning and implementation is an integrated process across all an organization's activities, it gives the opportunity to accomplish several goals with one activity. Three examples from the corporate world are relevant.

- Dow Chemical and WRAP: In 1986, building on a long-standing policy of reducing pollution, Dow introduced its Waste Reduction Always Pays (WRAP) program. Raw material losses from processes are addressed and measures to curtail the losses developed. The program has other components, but the point is common to all: Dow can both reduce emissions, saving money on its waste treatment efforts, and increase its efficiency in terms of saleable product per unit of raw material input.

- Northern Telecom's CFC replacement program: The 1990 Montreal Protocol, agreed to by 93 countries, set the goal of eliminating CFC and halon use by the end of the decade. Northern Telecom had begun its reduction program in 1988, and had successfully reduced its use of CFC-113 solvents from one million pounds in that year to zero by the end of 1991. The company invested $1 million and saved $4 million annually in solvent purchases.

- Monsanto's new (1995) process to make Roundup™: The research staff set out to develop a better manufacturing process for one of Monsanto's most important agricultural chemicals, one that would not require some of the toxic and volatile raw materials of the existing process. The result was a safer process which produces a purer final product and has almost no waste. The process won a 1996 President's Green Chemistry Award for its improvement on old technology.

These examples demonstrate that integrated goals can often be the most productive. The companies save money and improve environmental performance because (at least in part) they set out to find win-win solutions. It is a demonstration of the old adage: If you don't ask the right question, you won't get the right answer.

In this context it is clear that, for any large organization, managing environmental issues is no different from managing any other important, complex and pervasive set of issues. *Business Strategies for Sustainable Development* (IISD, 1992) looks at management issues in terms of commercial activities, but with a few changes of language it could just as well apply to a university, hospital or government department. The work of the Canadian Standards Association on environmental management and generic management systems (CSA, 1993) again uses the same basic concepts.

Using the general language of the *Generic Management System* document of CSA, all management systems need these attributes:

- Purpose: The organization knows what needs to be done.
- Commitment: It has the motivation to want to do it.
- Ability: It has the knowledge to do it.
- Learning: It learns from what it does, so it can improve.
- Action: The daily processes of the unit produce results that reflect the other four principles.

These attributes are equally valid for the department as a whole or for any of its operating units. They are also true for the various management tasks the organization carries out, be they financial management, personnel or safety management, facilities construction or environmental management.

The purpose attribute relates to the goals the organization wants to accomplish. In the public sector, commitments will reflect changing national attitudes with the environmental or ecological costs of production and business taking on a greater prominence as the absolute priority of economic growth as a goal is reduced. Therefore, as economic activities are measured against ecological and sustainability criteria, the balance of priorities will shift from time to time.

The topic of management systems for environmental and sustainable development management is explored further in a recent publication by the Auditor General of Canada “Environmental Management Systems: A Principle-based Approach” (Auditor General, 1995).

Because of the necessary integration of measurement approaches with overall management systems, one relevant set of indicators relates to the management system itself. Such indicators measure the existence of the management system, its characteristics, its degree of success in achieving its goals and ongoing improvements in these activities.

CHAPTER 6: PRACTICAL GUIDELINES FOR ASSESSMENT

While there is no one particular set of sustainable development indicators endorsed by all experts and practitioners, there are several general guidelines for developing and using measurement tools and indicators that can be synthesized from the many ongoing projects all over the world. Such guidelines can assist civil groups, governments and businesses in launching new assessment programs or revising existing ones. These guidelines can equally help government departments and agencies in their efforts to measure performance in achieving sustainable development. It is important to note that these guidelines are not identical with criteria of indicator selection. A number of projects and authors provide lists of selection criteria for environmental indicators (e.g., Liverman et al., 1988; VHB, 1989; Environment Canada, 1991; Tunstall, 1992; Hammond et al., 1995). Selection criteria for indicators of sustainable development are also available (e.g., Gosselin et al., 1991; Sustainable Seattle, 1993; BCRTEE, 1993; MacNeill and Runnalls, 1993; and LGMB, 1995).

The guidelines offered here have been developed by recognizing that indicators are only tools in the assessment process, and there are several conditions to their successful application that need to be specified (IISD, 1996).

The starting point of any assessment of progress toward sustainability is establishing a vision of sustainable development and clear goals that provide a practical definition of that vision in terms that are meaningful for the decision-making unit. In the case of the Government of Canada, this vision has been evolving, as officials work through Canada's response to the Brundtland Commission report, UNCED and many other milestones. The vision has recently been outlined in *A Guide to Green Government*, which clearly expresses the government's commitment to sustainable development.

A few important considerations affect both the content and the process of measurement. The content of the measurement should cover four closely related issues: it should be based on a holistic approach, it should include the essential elements that define sustainable development, it should have a well-defined scope, and it should focus on priority issues. The process of the measurement should be open and transparent, based on broad public participation, and helped by effective communication of its findings. It should clearly assign institutional capacity for measurement, and it should provide a mechanism for ongoing work.

Guidelines Concerning the Content of Measurement

A distinctive characteristic of sustainable development is its roots in a holistic approach. The measurement process also reflects this approach and includes a review of the whole system as well as its parts. In more concrete terms, this means that in identifying the relevant issues to be included in the measurement process, equal consideration is given to the well-being of human, ecological and economic sub-systems, their component parts and, most important, the interaction between the parts. At the same time, it also means that measures scan both positive and negative consequences of human activity, in a way that reflects the full costs and benefits for human and ecological systems, in both monetary and non-monetary terms.

As the concept of sustainable development includes several essential elements that ultimately define the focus of human activities, these elements are reflected in the measurement process. Without addressing them, the measurement would be distorted. These elements span over three major dimensions:

- issues concerning equity (equity and disparity within the current population and between current and future generations, over-consumption and poverty, human rights, access to services, each as appropriate in the measurement context);
- issues concerning the life-support system (ecological conditions on which life depends); and
- issues related to the success of economic development and other non-market activities that contribute to human and social well-being.

There are certain situations in which the measurement process cannot cover all the complex issues to satisfy requirements of a holistic approach and all the topics identified as essential elements. In fact, even broad national reports must have a practical focus. This is particularly true for smaller scale measurement projects such as for a government department. Consequently, the measurement of progress toward sustainability is based on narrowing down the task. It starts with the selection of an explicit set of categories or an organizing framework that links vision and goals to indicators and measurement criteria. These categories help select a limited number of key issues for analysis, while the issues provide the context within which a limited number of indicators or indicator combinations are selected to provide a clearer signal of progress. The practical focus also means that comparisons are used to assess progress (or lack of it). Measures and indicator values are compared to targets, reference values, ranges, thresholds or direction of trends as appropriate. Comparisons are also helped by standardizing measurement wherever possible. This makes the actual measurements technically easier and historical (trend) evaluations more reliable.

The measurement process should cover a temporally and spatially adequate scope. It should adopt a time horizon long enough to capture both human and ecosystem time scales and respond to current short-term decision-making needs as well as those of future generations. It also ensures that the study includes local as well as distant impacts on people and ecosystems. It builds on historic and current conditions to anticipate future conditions: where do we *want* to go, and where *could* we go?

Guidelines Concerning the Process of Measurement

Sustainable development is a concern for all, and it requires that people be given the opportunity to be informed about issues and conditions that influence their life in the present and the future. The openness of the measurement process provides such an opportunity. It means that the methods of measurement, the origin of data used, and the calculation and meaning of indicators are made public and accessible to all. It also means that all judgments, assumptions and interpretations in the measurement reports are made explicit, and the uncertainties in data and conclusions are admitted and spelled out.

Openness is a part of effective communication. The audience that is interested in sustainable development performance reviews includes the general public and experts, individual households and international organizations, and public and private sector decision makers. A focused process makes the measurement comprehensible for them. It draws from indicators and other tools that are stimulating and engage decision makers. Most important, the process of measurement from the outset aims for simplicity in structure and use of clear and plain language.

Broad participation is an often overlooked guideline of the measurement process, particularly when the evaluation affects internal departments of the public or private sector. Yet such participation is crucial for the implementation of the underlying values of sustainable development and the acceptance of recommendations for action. In a good process, broad representation of key grass-roots, social, professional and technical groups is obtained to ensure recognition of diverse values and the participation of decision makers thus securing a firm link to decision making and resulting actions.

Measurement simplifies a complex system that is constantly changing. Therefore, measurement is rarely considered definitive. We recognize uncertainty and learn to adapt as we go along by providing feedback to decision making between action and measurement. Ongoing assessment is an iterative, adaptive process, responsive to change. It promotes collective learning, encourages the development of a capacity for repeated measurement to determine trends and helps adjust goals, frameworks and indicators as new insights are gained.

The continuity of assessing progress toward sustainability is assured by clearly assigning responsibility and providing ongoing support for measurement in the decision-making process. An institutional capacity for data collection, maintenance and documentation is created that supports the development of local measurement capacity.

None of the above guidelines individually ensure that progress in sustainable development is adequately measured. Together, however, they can be used as a checklist to help design and improve measurement tools and procedures. When guidelines are followed, the selected sets of indicators are indeed tools for policy making and effective communication leading to action for sustainable development.

APPENDIX A: SUSTAINABLE DEVELOPMENT INDICATORS

Table A1
UN CSD Menu of Indicators for Sustainable Development, Based on Agenda 21

Chapters of Agenda 21	Driving Force Indicators	State Indicators	Response Indicators
Category: Social			
Chapter 3: Combating poverty	– Unemployment rate	– Head count index of poverty – Poverty gap index – Squared poverty gap index – Gini index of income inequality – Ratio on average female wage to male wage	
Chapter 5: Demographic dynamics and sustainability	– Population growth rate – Net migration rate – Total fertility rate	– Population density	
Chapter 36: Promoting education, public awareness and training	– Rate of change of school-age population – Primary school enrolment ratio (gross and net) – Secondary school enrolment ratio (gross and net) – Adult literacy rate	– Children reaching grade 5 of primary education – School life expectancy – Difference between male and female school enrolment ratios – Women per hundred men in the labour force	– GDP spent on education
Chapter 6: Protecting and promoting human health		– Basic sanitation: Percent of population with adequate excreta disposal facilities – Access to safe drinking water – Life expectancy at birth – Adequate birth weight – Infant mortality rate – Nutritional status of children	– Immunization against infectious childhood diseases – Contraceptive prevalence – Proportion of potentially hazardous chemicals monitored in food – National health expenditure devoted to local health care – Total national health expenditure related to GNP

Chapters of Agenda 21	Driving Force Indicators	State Indicators	Response Indicators
Chapter 7: Promoting sustainable human settlement development	– Rate of growth of urban population – Per capita consumption of fossil fuel by motor vehicle transport – Human and economic loss due to natural disasters	– Percent of population in urban areas – Area and population of urban formal and informal settlements – Floor area per person – House price to income ratio	– Infrastructure expenditure per capita
Category: Economic			
Chapter 2: International co-operation to accelerate sustainable development in countries and related domestic policies	– GDP per capita – Net investment share in GDP – Sum of exports and imports as a percent of GDP	– Environmentally adjusted Net Domestic Product – Share of manufactured goods in total merchandise exports	
Chapter 4: Changing consumption patterns	– Annual energy consumption – Share of natural-resource intensive industries in manufacturing value-added	– Proven mineral reserves – Proven fossil fuel energy reserves – Lifetime of proven energy reserves – Intensity of material use – Share of manufacturing value-added in GDP – Share of consumption of renewable energy resources	
Chapter 33: Financial resources and mechanisms	– Net resources transfer/GDP – Total ODA given or received as a percentage of GNP	– Debt/GNP – Dept. service/export	– Environmental protection expenditures as a percent of GDP – Amount of new or additional funding for sustainable development
Chapter 34: Transfer of environmentally sound technology, co-operation and capacity-building	– Capital goods imports – Foreign direct investments	– Share of environmentally sound capital goods imports	– Technical co-operation grants
Category: Environmental			
Chapter 18: Protection of the quality and supply of freshwater resources		– Groundwater reserves – Concentration of fecal coliform in freshwater Biochemical oxygen demand in water bodies	– Wastewater treatment coverage – Density of hydrological networks
Chapter 17: Protection of the oceans, all kinds of seas and coastal areas	– Population growth in coastal areas – Discharges of oil into	– Maximum sustained yield for fisheries – Algae index	

Chapters of Agenda 21	Driving Force Indicators	State Indicators	Response Indicators
	coastal waters Release of nitrogen and phosphorus to coastal waters		
Chapter 10: Integrated approach to the planning and management of land resources	– Land use change	– Changes in land condition	– Decentralized local-level natural resource management
Chapter 12: Managing fragile ecosystems: combating desertification and drought	– Population living below poverty line in dryland areas	– National monthly rainfall index – Satellite-derived vegetation index – Land affected by desertification	
Chapter 13: Managing fragile ecosystems: sustainable mountain development	– Population change in mountain areas	– Sustainable use of natural resources in mountain areas – Welfare of mountain population	
Chapter 14: Promoting sustainable agriculture and rural development	– Use of agricultural pesticides – Use of fertilizers – Irrigation percent of arable land Energy use in agriculture	– Arable land per capita – Area affected by salinization and waterlogging	– Agricultural education
Chapter 11: Combating deforestation	– Wood harvesting intensity	– Forest area change	– Managed forest area ratio – Protected forest area as a percent of total forest area
Chapter 15: Conservation of biological diversity		– Threatened species as a percent of total native species	– Protected area as a percent of total area
Chapter 16: Environmentally sound management of biotechnology			– R & D expenditure for biotechnology Existence of national biosafety regulations or guidelines

Chapters of Agenda 21	Driving Force Indicators	State Indicators	Response Indicators
Chapter 9: Protection of the atmosphere	– Emissions of greenhouse gases – Emissions of sulphur oxides – Emissions on nitrogen oxides – Consumption of ozone-depleting substances	– Ambient concentrations of pollutants in urban areas	– Expenditure on air pollution abatement
Chapter 21: Environmentally sound management of solid wastes and sewage-related issues	– Generation of industrial and municipal solid waste – Household waste disposed per capita		– Expenditure on waste management – Waste recycling and reuse – Municipal waste disposal
Chapter 19: Environmentally sound management of toxic chemicals		– Chemically induced acute poisonings	– Number of chemicals banned or severely restricted
Chapter 20: Environmentally sound management of hazardous wastes	– Generation of hazardous wastes – Imports and exports of hazardous wastes	– Area of land contaminated by hazardous wastes	– Expenditure on hazardous waste treatment
Chapter 22: Safe and environmentally sound management of radioactive wastes	– Generation of radioactive wastes		
Category: Institutional			
Chapter 8: Integrating environment and development in decision making			– Sustainable development strategies – Program of integrated environmental and economic accounting – Mandated environmental impact assessment National councils for sustainable development
Chapter 35: Science for sustainable development		– Potential scientists and engineers per million population	– Scientists and engineers engaged in R&D per million population – Expenditure on R&D as a percent of GDP

Chapters of Agenda 21	Driving Force Indicators	State Indicators	Response Indicators
Chapter 37: National mechanisms and international co-operation for capacity-building in developing countries			
Chapter 38: International institutional arrangements			
Chapter 39: International legal instruments and mechanisms			– Ratification of global agreements – Implementation of ratified global agreements
Chapter 40: Information for decision making		– Main telephone lines per 100 inhabitants – Access to information	– Programs for national environmental statistics
Chapters 23 -32: Strengthening the role of major groups			– Representation of major groups in national councils for sustainable development – Representatives of ethnic minorities and indigenous people in national councils for sustainable development – Contribution of non-governmental organizations to sustainable development

Source: UN CSD, 1996.

Table A2
List of National Environmental Indicators of Canada

Categories and Issues	Indicators
Atmosphere	
Climate change	• Canadian energy-related emissions of carbon dioxide (CO_2) • Atmospheric concentrations of CO_2 • Global air temperature
Stratospheric ozone depletion	• Canadian production and importation of ozone-depleting chemicals Stratospheric ozone levels
Radiation exposure	Levels of radioactivity in the air
Acid rain	Sulphur dioxide (SO_2) and nitrogen oxides (NO_x) emissions
Outdoor urban air quality	Common air pollutants • Nitrogen dioxide (No2) and carbon monoxide (CO): Levels in urban air and emissions • SO_2 and total suspended particulates (TSP): Levels in urban air emissions • Ground-level ozone concentrations Air toxins • Lead concentrations in urban air
Water	
Freshwater quality	• Population served by treated water supply • Municipal discharges to fresh water: BOD (biochemical oxygen demand), TSS (total suspended solids) and phosphorous • Pulp and paper mill discharges to fresh water: TSS and BOD • Discharges of regulated substances by petroleum refineries to water • Concentrations of phosphorus and nitrogen in water • Maximum observed concentrations, of pesticides in water: 2,4-D, atrazine and lindane
Toxic contaminants in the freshwater ecosystem	• Contaminant levels in herring gull eggs in the Great Lakes Basin: PCBs (polychlorinated biphenyls) and DDE (dichlorodiphenyldichloroethylene) • Contaminant levels in lake trout, a sport fish from the Great Lakes Basin: PCBs and DDT (dichlorodiphenyltrichloroethane)
Marine environmental quality	• Municipal discharges to coastal waters: TSS and BOD • Pulp and paper mill discharges to coastal waters: TSS and BOD • Volume of significant marine spills • Area closed to shellfish harvesting • Contaminant levels in seabird eggs: PCBs • Contaminant levels in seabird eggs: Dioxins and furans
Biota (Living Organisms)	
Biological diversity at risk State of wildlife	• Wildlife species at risk
Land	

Categories and Issues	Indicators
Protected areas Urbanization Solid waste management	• Land under protected status • Rural to urban land conversion • Municipal solid waste disposal trends
Natural Economic Resources	
Forestry	• Regeneration success vs. total forest area harvested
Agriculture	• Changes in agricultural land use • Amount of chemical fertilizer used and its associated nutrient content • Agricultural pesticide application on cultivated land
Fisheries	• Total commercial fish catches in Canadian waters off the Atlantic coast • Commercial fish harvest in the Great Lakes
Water use	• Total water withdrawal compared with growth in GDP • Rates of water withdrawal and consumption by key economic sectors • Rates of water recirculation by key industrial sectors • Daily household water use per capita
Energy	• Total per capita primary energy use • Emissions of CO_2 per unit of energy consumed • Fossil fuel intensity of primary energy demand

Source: Environment Canada, 1991.

Table A3
Partial List of Rudimentary Indicators for
Sustainable Development, Canada

Ecosystem
• Temperature (daily and trends over time) • Concentrations of contaminants in indoor and outdoor air that are common (CO_2, NO_2 ground-level ozone, carbon monoxide); and toxic (dioxins, lead, etc.) • Concentrations of contaminants in water (mercury, DDT, PCBs, etc.) • Concentrations of contaminants in the tissue of fish, birds, wildlife and humans (lead, PCBs, DDT, etc.) • Rates of soil erosion • Acid deposition • Loss of wildlife habitat • The state of biodiversity: • Genetic (diversity within species) • Species (diversity in the number of distinct species) • Species health (births, survival rates, deformities, leaf or needle loss, etc.) • Population shifts of wildlife (eagles, caribou, counts of migrating salmon in the Fraser River, etc.)
Interaction
• Contribution to well-being by activity (value-added by agriculture, manufacturing, financial services, housework, etc.) • Resource use (per unit of time or per unit of output) • Generation of contaminant emissions • Heat and waste products per capita or per unit of production • Loading to air, surface water, groundwater or land by activity (by automobiles, pulp and paper manufacturing, energy production, etc.) • The totals for regions and the nation • Proportion of materials recycled • Renewable resource harvest rates • Non-renewable resource extraction rates • Degree of compliance with laws and regulations
People
• Infant mortality rates • Literacy rates • Life expectancy at birth • Incidence of disease • Employment and unemployment rates • Income levels • Degree of pride in community and culture • Corporate bankruptcies • Level of indebtedness (individual, community and nation) • Obesity (adults) • Malnutrition (children) • Caloric intake and the proportion of it acquired from local, Canadian and foreign foods

Source: NRTEE, 1995.

Table A4
President's Council List of Sustainable Development Indicators, United States

Goals	Indicators of Progress
Health and the environment	Clean air Drinking water Toxic exposures Diseases and mortality
Economic prosperity	Economic performance Employment Poverty Savings and investment rates Natural resources and environmental accounting Productivity
Equity	Income trends Environmental equity Social equity
Conservation of nature	Ecosystems Habitat loss Threatened and endangered species Nutrients and toxics Exotic species Global environmental change
Stewardship	Materials consumption Waste reduction Energy efficiency Renewable resource use
Sustainable communities	Community economic viability Safe neighbourhoods Public parks Investment in future generations Transportation patterns Community access to information Shelter Metropolitan income patterns Infant mortality
Civic engagement	Public participation Social capital Citizen participation Collaborations
Population	Population growth Status of women Unintended pregnancies Teen pregnancies Immigration
International responsibility	International assistance Environmental assistance

Goals	Indicators of Progress
	Assessment of progress Environmental technology exports Research leadership
Education	Information access Curriculum development National standards Community participation National achievement Graduation rates

Source: The President's Council, 1996.

Table A5
Inter-Agency Working Group on Sustainable Development Indicators: Proposed Indicator Definitions

SDI Name	SDI Definition
Capital assets	Total value, in dollars, of U.S. tangible reproducible capital, excluding all public infrastructure, as defined in the National Asset Accounts
Community group participation	The average number of hours per week per capita devoted to participation in community organizations
Consumption expenditures per capita	Total dollar value of goods and services purchased by consumers per year as defined in the National Income Accounts
Contaminants in biota	Chemical contaminants in land, estuarine and marine biota
Crime rate	Overall crime rate for the United States
Energy consumption per capita	Total energy consumption divided by total population organized by type of energy source (coal, oil, gas, nuclear, renewable, etc.)
Family function	Measure of families effectively performing their basic functions. This serves as a placeholder until a better, more specific measure gets defined.
Fish catch to growth ratio	Total fish landings (including by-catch) divided by the fish population growth rate
Greenhouse climate response index	Arithmetic average of 1) percent of United States with much above normal minimum temperatures, 2) percent of United States with much above normal precipitation during the months of October through April, 3) percent of United States in extreme or severe drought during the months of May through September, and 4) the percent of United States with a much greater than normal proportion of precipitation derived from extreme one day precipitation events (exceeding 2 inches)
Greenhouse gas emissions	Emissions of greenhouse gases: CO_2, CH_3, NO_2, CFCs and ozone
Groundwater contamination	Area of land with contaminated groundwater
Income distribution	Distribution of income per capita arranged to show the percentage of the population at various levels of income

SDI Name	SDI Definition
Invasive exotic species	The total number of invasive species and their distribution in the United States
Investment percentage of GDP	Investment share of GDP (%), including research, technology development, invention and innovation, as defined in the National Income Accounts. Includes both public and private investment
Major land use including urban	The total land area in the United States broken down by major estuarine and land ecosystem. Includes both urban and agricultural land
Materials use per capita	Total metric tons of materials in use divided by total population organized by type, including recycled
Outdoor recreation services	Total number of visitor days per person attributed to outdoor recreation and tourism
Ozone depleting substances	Production and consumption of ozone-depleting substances
People in clean air non-attainment areas	Number of people living in areas that do not meet air quality standards
Population health	A placeholder indicator to measure the status of health in the population
Receipt of health care	% of population with adequate access to health care as a function of income level
Soil types	Land area organized by soil type
Species in trouble	The total number of species in trouble in the United States
Teacher capabilities	The average capacity or skill level of individual teachers to instruct students
Test scores by economic group	Standardized achievement test scores organized by economic group
Timber harvest to growth ratio	Total timber harvest divided by total timber growth rate per year
Total managed waste	Total mass of waste management in man-made facilities in the United States organized by type (including nuclear), by site and by hazard level. This does not include waste already released in the environment or in abandoned, uncontrolled sites
Total population	Total population in the United States organized by geographic area
Toxic land area	Area and percent of land experiencing an accumulation of persistent toxic substances, including superfund and brown field sites
Water consumption to renewal ratio	Total water consumed per year divided by the total water resource growth rate per year
Water quality index	Index of water quality measuring the appropriate concentrations of selected chemical, physical and sanitary constituents of water at stations
Work force skill level	The average level of experience, capability, knowledge and social skills of the individuals in the work force

Source: Courtesy of David Berry, Executive Director, Inter-Agency Working Group on Sustainable Development Indicators, Washington, DC, 1996, unpublished.

Table A6
Sustainable Development Indicators, Alberta

1.	Air quality index
2.	Exposure to substandard ambient air quality
3.	Production of acid-forming emissions
4.	Purchase of ozone-depleting substances
5.	Emission of carbon dioxide and other greenhouse gases
6.	Area of land affected by soil erosion and salinity
7.	Total area of contaminated sites
8.	Area of lands under formal agreement for wildlife habitat
9.	Number of commercial crop varieties
10.	Number of biogeographical regions with adequate protected areas
11.	Number and size of recreational, cultural and spiritual sites
12.	Percent of urban areas in parks and playgrounds
13.	Total area in significant land use categories
14.	Percent of harvested forest that is successfully restocked
15.	Waste per capita going to landfills
16.	Size and distribution of significant wetlands
17.	Groundwater quality index
18.	Lake water quality index
19.	Condition of major rivers
20	Length of heritage rivers
21.	Percent of run-off treated at primary, secondary and tertiary levels
22.	Per capita water consumption
23.	Water resource depletion rates
24.	Number of species at risk
25.	Proportion of species approaching target population size
26.	Population of species for which Alberta has a key custodian role
27.	Efficiency of non-renewable resource recovery and use
28.	Proportion of energy from fossil and non-fossil fuel sources
29.	Per capita energy consumption
30.	Employment index
31.	Average education level attained
32.	Percent of post-secondary graduates finding employment in their field
33.	Job satisfaction index
34.	Percent of Albertans on welfare
35.	Volunteer rate
36.	Percent of population taking each mode of transportation to work
37.	Average commuting distance to work
38.	Population growth
39.	Urban and rural crime rates
40.	Percent of GDP spent on research and development
41.	GDP per capita
42.	GDP per capita adjusted for natural resource depreciation
43.	Percent of GDP from secondary production and business services

44.	Number of environmental services, products and technologies exported
45.	Per capita debt
46.	Accumulated depreciation of natural resources
47.	Degree of non-compliance with environmental regulations
48.	Percent of performance-based regulations
49.	Percent of sustainable-development-compatible legislation
50.	Public perception of information accessibility
51.	Percent of organizations that have adopted sustainable development
52.	Percent of management job descriptions including sustainable development
53.	Sustainable development literacy of the public
54.	Amount of foreign aid contributed
55.	Frequency of sustainable development in K-12 curricula
56.	Market value of permits traded or sold
57.	Percent of products and services where price reflects lifecycle cost
58.	Percent of recyclable products actually recycled
59.	Number of people involved in recycling initiatives

Source: ARTEE, 1994.

Table A7
Oregon Benchmarks Indicators

Classification of Indicators	Sub-Classes of Indicators	Indicators
Children and families	Early childhood development	Percentage of children that kindergarten teachers feel are ready to succeed in school
	Teen pregnancy	Pregnancy rate per 1,000 females ages 10-17
	Drug-free babies	Mothers not using alcohol during pregnancy
		Mothers not using tobacco during pregnancy
		Mothers not using illicit drugs during pregnancy
	Drug-free teens	Free from involvement with alcohol in the previous month
		Free from involvement with illicit drugs in the previous month
		Free from involvement with tobacco in the previous month
	Safe child care	Child care facilities which meet established basic standards
Education and work force preparation reforms	Educational skill levels	Composite reading and math skills (students achieving established skill levels)
		Composite writing skills (students achieving established skill levels)
Work force training	Job skill preparation	High school students with significant involvement in professional-technical education and entrepreneurial programs

Classification of Indicators	Sub-Classes of Indicators	Indicators
	Disabled students	Disabled high school graduates moving to competitive or supported employment
	Work force adaptability	Displaced workers re-employed within 24 months and earning at least 90% of previous income
Value-added products, global business	Value-added natural resource products	Value-added manufacturing as a percentage of total industry employment
	International trade	Manufactured goods sold outside of the United States
Health and health care	Health care access	Percentage of Oregonians with economic access to basic health care
	Rural health care	Oregonians with geographic access to basic health care
	Health care costs	Costs relative to 1980 costs
	Human immuno-deficiency virus	Annual percentage of HIV cases with an early diagnosis
		Total number of HIV cases with an early diagnosis
Physically livable communities	Air quality	Oregonians living where the air meets government air quality standards
	Affordable housing	Oregon households below median income spending less than 30% of their household income on housing
	Mobility	Vehicle miles traveled per capita in Oregon metropolitan areas
	Public safety	Number of communities involved in a community-based strategic plan for law enforcement
		Average rate of reincarceration of paroled offenders within three years of initial release
Socially livable communities	Arts and culture funding	Rank in per capita funding
	Hate crimes	Reported crimes against people or property motivated by prejudice per 100,000 Oregonians
Clean natural environment	Stream flow	Key rivers and streams with in-stream water rights meeting in-stream flow needs nine or more months out of the year
	Stream quality	Miles of assessed Oregon rivers and streams not meeting state and federal government in-stream water quality standards
	Salmon	Key sub-basins in which wild salmon and steelhead populations are increasing or at target levels
Government efficiency: revenue reform	Taxes	Oregon ranking in state and local taxes per capita
	Public infrastructure investment	Real per capita outlays for facilities

Classification of Indicators	Sub-Classes of Indicators	Indicators
	Public agency performance	Oregonians who think the government is doing a good job providing government services
		Agencies the employ results-oriented performance measures
Education	Student skills	11th grade students who achieve skill proficiency: composite reading and math skills
		11th grade students who achieve skill proficiency: composite writing skills
	Comparative math skills	Ranking of 12th grade students on international math assessments
	Adult education attainment	Adults who have completed high school or equivalent program
		Adults who have completed baccalaureate degree
	Adult literacy	Adults with intermediate proficiency at prose literacy
		Adults with intermediate proficiency at document literacy
		Adults with intermediate proficiency at quantitative literacy
Individual and family health	Adult health	Adults with good health practices
	Family stability	Children ages 0-17 living 100% above the poverty level
		Number of children abused or neglected per 1,000 persons under 18
Clean environment	Air quality	Oregonians living where the air meets government air quality standards
	Natural resource lands	1970 agricultural land still preserved for agricultural use
		1970 forest land still preserved for forest use
		1990 wetlands still preserved for wetlands
	Groundwater	Quantity of Oregon groundwater
Livable communities	Affordable and available housing	Oregon households that can afford the median-priced Oregon home for sale
	Transportation	Oregonians who commute (one-way) within 30 minutes where they live and where they work
		Oregonians living in communities with daily scheduled inter-city passenger bus, van or rail services
	Sense of community	Index crimes per 1,000 Oregonians
		Oregonians who volunteer at least 50 hours of their time per year to civic, community or non-profit activities
		Eligible Oregonians who vote
		Oregonians with positive view of the state
Personal income, economic diversity and international trade	Personal income	Oregon's real per capita income as a percentage of the U.S. real per capita income
		Level of real per capita income
		Income per capita as a percentage of the Oregon overall per capita income
		Oregonians in the middle income range
		Average annual payroll per covered worker (all industries, 1990 dollars)

Classification of Indicators	Sub-Classes of Indicators	Indicators
	Economic diversity	Manufacturing employees outside of state's five largest manufacturing industries
		Percentage of Oregonians employed outside the Portland tri-county area
	Manufacturing exports	Manufactured goods sold outside of the United States

Source: Oregon State Progress Board, 1992.

Table A8
Sustainable Seattle Indicator Sets

Classification of Indicators	Indicators
Environment	Wild salmon runs through local streams
	Biodiversity in the region
	Number of good air quality days per year, as reported by the pollution standards index
	Amount of topsoil lost in king county
	Acres of wetlands remaining in king county
	Percentage of Seattle streets meeting "pedestrian-friendly" criteria
Population and resources	Total population of King County (with annual growth rate)
	Gallons of water consumed per capita
	Tons of solid waste generated and recycled per capita per year
	Vehicle miles travelled per capita and gasoline consumption per capita
	Renewable and non-renewable energy consumed per capita
	Acres of land per capita for a range of land uses (residential, commercial, open space, transportation, wilderness)
	Amount of food grown in Washington, food exports and food imports
	Emergency room use for non-emergency purposes
Economy	Percentage of employment concentrated in the top 10 employers
	Hours of paid employment at the average wage required to support basic needs
	Real unemployment, including discouraged workers, with differentiation by ethnicity and gender
	Average savings rate per household
	Reliance on renewable or local resources in the economy
	Percentage of children living in poverty
	Housing affordability gap
	Health care expenditures per capita
Culture and society	Percentage of infants born with low birth weight
	Ethnic diversity of teaching staff in elementary and secondary schools

Classification of Indicators	Indicators
	Number of hours per week devoted to instruction in the arts for elementary and secondary schools
	Percent of parent/guardian population involved in school activities
	Juvenile crime rate
	Percent of youth participating in some form of community service
	Percent of enrolled 9th graders who graduate from high school
	Percent of population voting in odd-year (local) primary elections
	Adult literacy rate Average number of neighbours the average citizen reports knowing by name
	Equitable treatment in the justice system
	Ratio of money spent on drug and alcohol prevention and treatment to money spent on incarceration for drug and alcohol related crimes
	Percentage of population that gardens
	Usage rates for libraries and community centres
	Public participation in the arts
	Percent of adult population donating time to community service
	Individual sense of well-being

Source: Sustainable Seattle, 1993.

APPENDIX B: CALCULATION OF THE COMPONENT INDICES OF THE BAROMETER OF SUSTAINABILITY

The Barometer of Sustainability is a combination of ecosystem and human well-being, each measured individually by its respective indices.

Index of Ecosystem Well-Being

The first component of the Barometer of Sustainability is the index of ecosystem well-being (IEW). This index identifies the trends in ecosystem function over time. The IEW is a function of land (L), water (W), air (A), biodiversity (B) and resource use indicators (RU). These components are equally weighted and then averaged to obtain the IEW. The value of the IEW is ranked on a scale of 0 (worst) to 100 (best).

$$Index\ of\ Ecosystem\ Well-being = \left\{ \frac{L + W + A + B + RU}{5} \right\}$$

One of the sub-indices of the ecosystem well-being index is the index of land naturalness (BC Commission for Resources and Environment, 1996). This index indicates the degree to which land use changes over the years. The index is a function of the area of natural land (N), modified land (M), cultivated land (C) and built up land (B). Land use categories are weighted based on their degree of modification, 0 (built land) to 1 (natural land), and then summed to obtain the index number. Due to a lack of information on the area of modification and naturalness, this index only provides rough estimates of the trends in land use.

$$\begin{matrix} Index\ of\ Land \\ Naturalness \end{matrix} = \sum w_i \left(N + M + C + B \right)$$

where: wi = weighting factor of natural, modified, cultivated and built land

A second sub-index of the ecosystem well-being index is the water quality index (WQI) (Water Quality Branch, British Columbia's Ministry of the Environment, Land and Parks) which assesses the quality of water systems that are subject to industrial, municipal and/or agricultural discharges. Monitored pollutants for the WQI vary with each body of water and the problems each body of water faces. However, the most common pollutants affecting water quality are acidity, nutrients, algae, particulate matter, cyanide, PCBs, nitrogen, chlorine, fluoride, aluminum, copper, lead, mercury, molybdenum and fecal coliforms. The index was computed based on differences between monitored water and water quality objectives for each pollutant, i.e., water quality is a function of the number of observation that do not meet water quality objectives, the frequency of observations that do not meet water quality objectives and the amount by which observations do not meet objectives. The WQI ranks water quality based on the pollutants' impacts on water uses: drinking, recreation, irrigation, livestock watering, use by aquatic life and use by wildlife. To convert these water use rankings to a rating for the Barometer of Sustainability scale, a rank of excellent on the use scale is converted to 90 (good); good is converted to 70 (OK); fair is converted to 50 (intermediate); etc. The converted scores are then weighted by their frequency of occurrence to calculate the overall value of water quality.

$$Water\ Quality\ Index = f\left\{\sum(Ii \neq Io), Freq(Ii \neq Io), \sum(Ii - Io)\right\}$$

$$where{:}\ Ii = actual\ observation\ of\ pollutant\ i$$

$$Io = value\ of\ pollutant\ i\ objective$$

Index of Human Well-Being

The second component of the Barometer of Sustainability, is the index of human well-being (IHW) which represents the overall level of human well-being. The IHW is a function of the wellness of individuals: health (H), education (E), unemployment (U), poverty (P), earnings (EA) and crime (C); plus business (B) and human action (HA). These three indicators are equally weighted and averaged to obtain the IHW. As in the IEW, indicators of human well-being are rated on a performance scale of 0 (worst) to 100 (best).

$$Wellness\ of\ Individuals\ (WI) = \frac{\sum(H + E + U + P + EA + C)}{6}$$

$$IHW = \frac{\sum(WI + B + HA)}{3}$$

Source: Prescott-Allen, 1995.

APPENDIX C: CALCULATION OF THE HUMAN DEVELOPMENT INDEX

To calculate the human development index (HDI) a minimum and a maximum value[1] are set for each indicator (X_{ij}) and each country's standing for each indicator is compared to the minimum and maximum range. The proportion of distance travelled between the minimum and maximum (d_{ij}) is calculated for each indicator. Finally, all indicator values are averaged to obtain the average indicator of deprivation (D_{ij}) and then subtracted from a value of 1 to provide each country's overall standing on the HDI index (HDI_j).

$$d\,ij = \frac{\max j\ X\,ij - X\,ij}{\max j\ X\,ij - \min X\,ij}$$

$$D\,j = 1/3 \sum d\,ij$$

$$\textit{Human Development Index} = (1 - D\,j)$$

$$where: i = \text{indicator } 1,2,3$$
$$j = \text{country } 1,2,\ldots,130$$

[1] The minimum and maximum values, once determined by the values of the best and worst performing countries, are now based on the most extreme values observed or expected over 60 years (fixed values).

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