Indicators of sustainability: indicators in various scientific disciplines

Report

Author(s):
Spreng, Daniel T.; Wils, Annababette

Indicators of Sustainability:
Indicators in Various Scientific Disciplines

Daniel Spreng (ETH Zurich) and Annababette Wils (MIT)

September 1996
(with some revisions in October 2000)

Contents:

Executive Summary

This paper was written in support of the project *Multidimensional Approaches to Sustainability: The Framing Project* proposed to the "Alliance for Global Sustainability" (AGS). The Introduction discusses the meaning of indicators, their functions, and guidelines for their development. The bulk of the paper describes sustainability indicators in five areas of interest

Indicators are primarily descriptive, quantitative units of information on a significant state or development intended to quantify, simplify, and monitor performance in a system. They may be intended to educate and communicate findings to the general public, facilitate political decisions, and/or help evaluate measures and policies.

Indicators may be constructed using a bottom-up, top-down, causal-chain, or limits approach. The bottom-up approach frequently uses an 'information pyramid' to screen information and reduce complexity as the levels of primary data and analysed data are sequentially traversed and then encapsulated in indicators and indices. An example of a top-down approach to environmental indicators is offered which moves from vision to strategy, targets, and standards before reaching indicators. Causal-chain indicators trace the causality inherent in a system. The "Indicator-Workshop Task" proposes to examine all construction methods in the search for subject-independent strategy elements.

The paper gives an overview of indicators in five areas: technological systems, social and political systems, natural environment, economy, and sustainability. The same indicator may be used in multiple fields of inquiry (e.g. emission of waste water in both technical and environmental systems), and its categorization depends on its intended purpose. Technical indicators, traditionally descriptive of equipment, have increasingly been developed to describe larger systems (e.g. Life Cycle Analysis, energy indicators for buildings, fuel economy for car fleets in the American automobile industry). Social indicators, both objective and subjective, have come to be increasingly featured in the reporting on national, sub-national, and international conditions and have been more widely discussed in connection with sustainable development. Composite and ratio environmental indicators abound that gauge the effect of human intervention in natural systems. Other indicators that assess the effect of human activity on the environment include stress models (e.g. Pressure State Response models), actor-acceptor models, man-environment-man models, and space-ship earth models. Macro and microeconomic indicators are among the most commonly reported indicators: GDP, unemployment, Stock market indices, company balance sheets, and the like. Partly to address deficits in traditional economic theory, environmental economics has recently begun to extend the scope of economic consideration and indicator use to natural resource matters. Sustainability indicators involve measurements of economic functioning as it relates to environmental protection and aspects of inter-

and intra-generational equity. Researchers in academia and international institutions are developing sustainability concepts and indices such as the human development index, the Index of Sustainable Economic Welfare, and Literate Life Expectancy, which, along with dynamic and linked natural/socio-economic measures, may be the basis for broad sustainability indicators.

Introduction: Role and Characteristics of Indicators

Sustainable development is a concept with many attractions. One characteristic of the concept is its openness. However, this also means that the concept is sometimes vaguely used and badly understood. One way to clarify our thinking on sustainable development is to gather relevant quantitative data. and to properly organize this data. While it is important to preserve the open character of the concept, many facets of sustainable development lend themselves to quantitative assessment. It is then equally important to develop a strategy to organize relevant data, i.e. to devise useful indicator systems and to enhance the understanding of them and their relationships to each other.

The paper is organized as follows: The remainder of the introduction discusses general principals of indicator construction. Sections 1 – 5 sketch some of the ideas on indicators in five areas of interest. These recent contributions to the discussion of the sustainability indicators include various frameworks to assess indicators, as well as lists of indicators. The five areas are technological systems, social and political systems, natural environment, economy, and sustainability criteria.

An indicator is information – usually quantitative – pointing to a matter (state or development) of some significance. The relationship between the indicator and the subject can be immediate or indirect. The hands of a clock indicate what time it is. In as far as the clock and the time zone are correct the hands immediately indicate the subject of interest, time. Body temperature is an indirect measure. When we feel under the weather, we take our temperature to decide whether or not to go to work. The readings on the thermometer do not say "go to work" or "do not go to work." There is much personal and societal experience involved in translating the body temperature reading into the decision to go to work or not.

What is an indicator good for?

The role of an indicator is:

- to monitor performance (over time and across cases)
- to quantify (reduce uncertainty) and
- to simplify (reduce complexity).

Generally, "indicators fulfil the social purpose to improve communication" (WRI 1995, p.1)[1]. Depending on who the audience of that communication process is, indicators should

- describe and diagnose trends of states and developments and identify limiting factors,
- educate the general public,
- help prepare political decisions and
- contribute to evaluating measures that have been undertaken.

The communication aspect is central to determining the best uses for indicators. The information portrayed in indicators has, time and again, been sufficient to lead and change behavior. For instance, the introduction of the GNP has lead governments to base policies on their expected influence on this indicator.

How should indicators be constructed?

Indicators can be constructed using a bottom-up, top-down, causal-chain, or limits approach. The following describes some of the efforts in each of these perspectives.

The "information pyramid" shown in Figure 1 places indicators in a successive line upwards from a vast body of primary data; to analyzed data on several hierarchical levels; to a higher level with simplified information in the form of indicators; and finally to the top of the pyramid with a small number of aggregate indices. The image of the pyramid is good when one thinks of this complexity reduction not only as compression but also as a screening of information.

This information pyramid was developed for sustainability indicators, but in fact such a pyramid is in use everywhere. Wherever indicators are used, they are the reduction and screening of a vast bottom, empirical base of data to an intermediate range, to a further concentration of a few "top" indices (often aggregates of indicators).

However, a bottom-up approach does not begin with the available data. First, someone must look for data set up or follow some rules of data collection. Once data are available, very often in abundance, there is some danger that the bottom up

---

[1] Allen Hammond et al., "Environmental Indicators: A systematic approach to measuring and reporting on environmental policy performance in the context of sustainable development", World Resources Institute, 1995

approach is done by a bureaucratic compression procedure. The bottom-up approach can, however, also involve a creative screening procedure: based on one's principal concern, one can decide whether one piece of data is of significance beyond the measured quantity and beyond their immediate first use and pick them as candidates for indicators. If the concern is the health of an individual, body temperature is a good indicator beyond the narrow fact of how warm that individual's body is.
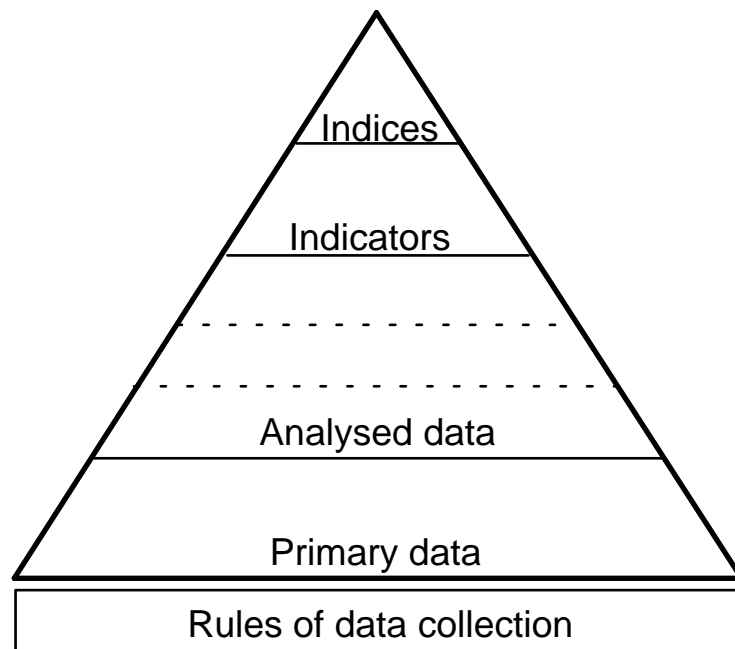
Figure 1: The Information Pyramid (adapted from WRI, 1995, p.1).

Taking the main concern, such as health or environmental quality, as the starting point leads us to the complementary approach the "top-down" method.

An example of the top-down approach, this time for the environment, is given by the German Council of Environmental Experts[2]. This council recommends to always construct environmental indicators based on a "Leitbild", a common, agreed upon vision, and to derive successively the "Handlungsprinzipien", i.e. the strategy, environmental quality targets and standards. Indicators, according to the council, should show the difference between the actual

[2] Der Rat von Sachverständigen für Umweltfragen, "Umweltgutachten 1994", Verlag Metzler-Poeschel, Stuttgart, 1994

Vision (Leitbild)	Sustainable, evironmentally sound development, taking necessary precautionary measures

Strategy (Handlungs-prinzipien)	- Use of renewable resources is smaller than their growth rate - Use of non-renewable resources = conservation/substitution - Preservation of environmental functions - Rate of emission = rate of assimilation - Preservation of human health

Environ-mental Quality Targets	- Critical resource use - Critical burdens respecting carrying capacity - Critical stress on human health

Environ-mental Quality Standards	- Critical reserves - Critical concentrations - Critical emission rates - Critical structural changes - Acceptable health risks

Indicators show the difference between actual state of the environment and quality standards (desired state)

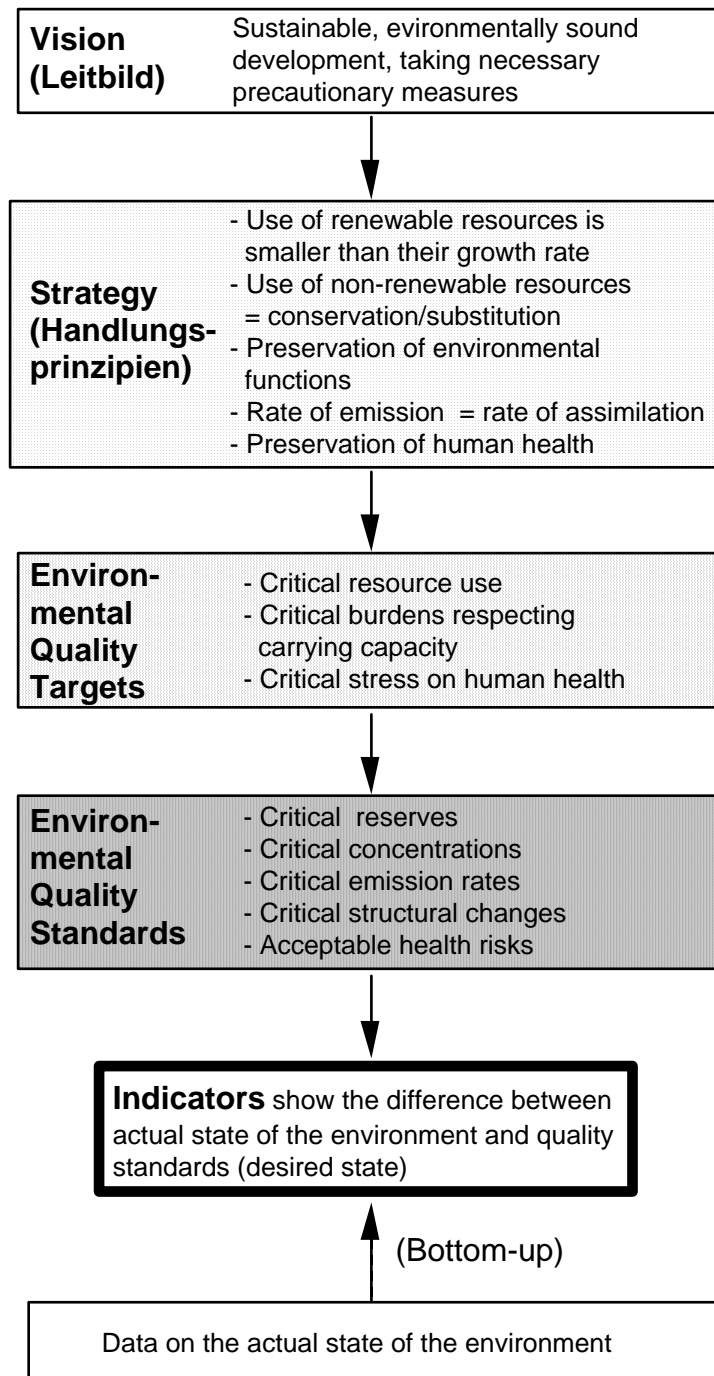(Bottom-up)

Data on the actual state of the environment

Figure 2: Top-down approach to the development of environmental indicators (SRU 1994)

state of the environment and the desired state. The approach presupposes the availability of environmental quality standards. In steps, their approach can be

broken down into four, shown in Figure 2. Each of the four steps may be very difficult in practice and the indicators derived this way may be difficult to communicate.

Another way to approach indicators is by distinguishing the subject matter they refer to and by understanding causality in the system and using indicators to trace that causality. This approach is proposed by e.g. McLaren (Figure 3)[3] and many others. This figure should be read as follows: indicators refer either to conditions, stresses, or responses (compare section 3) and are based on one or perhaps a combination of the other aspects.

It appears to us that all of these approaches have merit. In the course of the proposed project, we will learn whether there is perhaps a general pattern in the strategy of creating indicator systems that is independent of the subject matter under study.

---

[3] Virginia W. Maclaren, "Urban Sustainability Reporting", *Journal of the American Planning Association,* Vol. 62, No. 2, Spring 1996

Domain Based
• Environment
• Economy
• Society

Goal Based
• Carrying Capacity
• Basic Human Needs
• Social Well-Being
• Economic Prosperity
• Participation in Governance
• ...

Sectoral
• Housing
• Welfare
• Recreation
•Transportaion
• Environment
• Economic Development

Issue Based
• Urban Sprawl
• Solid Waste Management
• Crime and Safty
• Job Creation
• Industrial Pollution
• ...

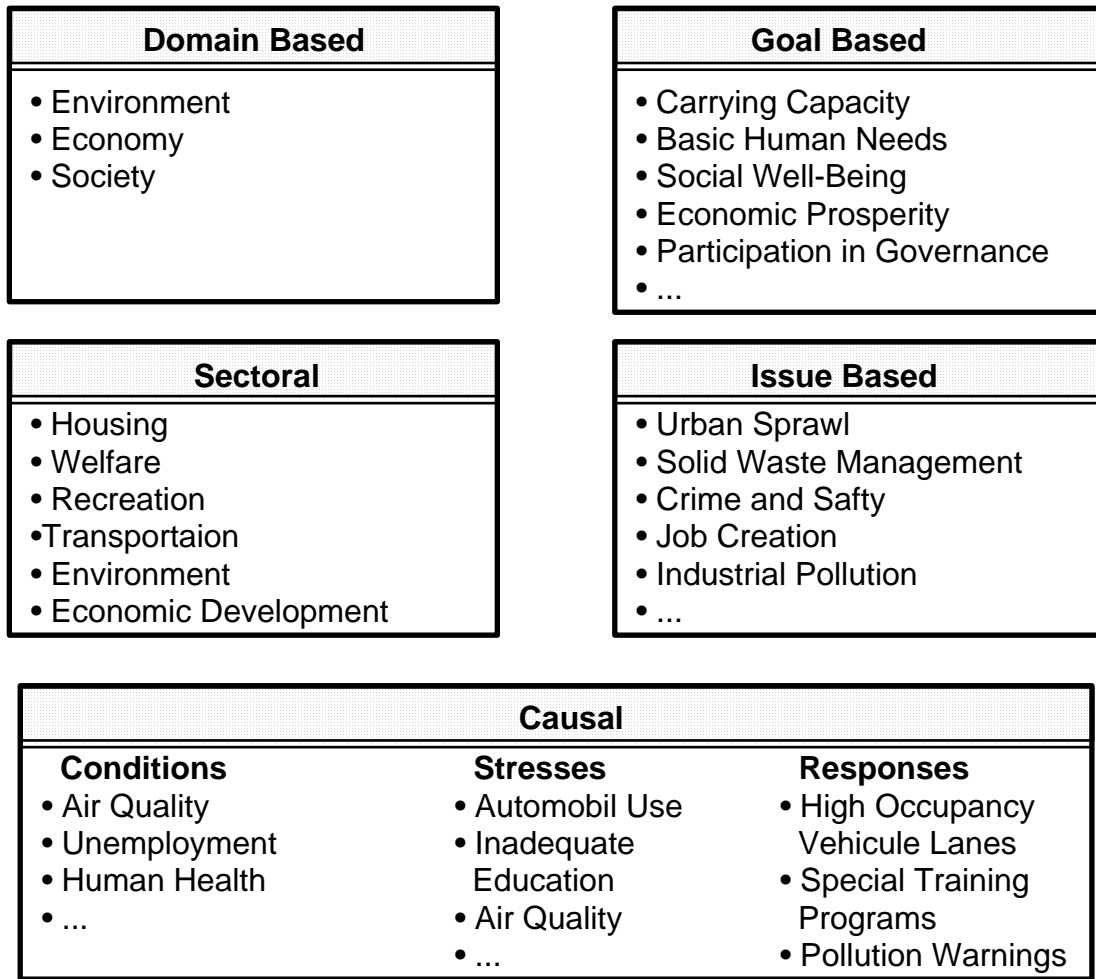| **Causal**		
Conditions	**Stresses**	**Responses**
• Air Quality	• Automobil Use	• High Occupancy Vehicule Lanes
• Unemployment	• Inadequate Education	• Special Training Programs
• Human Health	• Air Quality	• Pollution Warnings
• ...	• ...	

Figure 3: Maclaren's typology of frameworks for sustainability indicators development[4]

Not included in this Figure is the distinction "procedural" and "analytic" indicators

Indicators in Various Scientific Disciplines

Researchers in all branches of scientific endeavor, including recent interdisciplinary approaches to sustainability, have developed measures of performance, or indicators, for the system they are interested in. Some of these indicators are widely accepted and take on unique values, such as body temperature as an indicator of health, while others are much more controversial and vague. This appendix reviews some of the important indicators in wide fields of scientific research and in four other broad fields: technology, society and politics, natural environment, economy. In addition, it examines the relation of these indicators to sustainable development.

This raises the question, how can we distinguish which are the technical, social, environmental, economic or sustainability indicators? Some indicators are used in more than one of the five fields. In that case, it is not so much the exact definition, which distinguishes say, an environmental from a technical indicator, as its intended purpose. The same indicator can be part of both a technical indicator system and an environmental indicator system. For example (see Figure 4), numbers which refer to the impact of a paper mill on the surrounding aquatic system are technical indicators if their purpose is to monitor changes of that impact due to changes in the paper mill (technology, product mix), and they are environmental indicators if their purpose is to monitor concomitant changes of the aquatic system (level of ground water, pollution, or fish population in a down-stream section of the river).

Thus, it is not so much the exact definition that distinguishes a environmental from a technical indicator as its intended purpose, and the same indicator can be part of both a system of technical indicators and a system of environmental indicators. The same is true for the distinction of social indicators from other indicators.

One obvious area where indicators will overlap is in the interface between research on sustainability and the environment and research on sustainability and the economy. However, this is not of great concern to us as the object of this project is not to make a neat

Emission of waste water ○

A

B

C

Technical changes A, B, C

Emission of waste water ○ and
number of fish in down-stream river □

1970   1980   1990
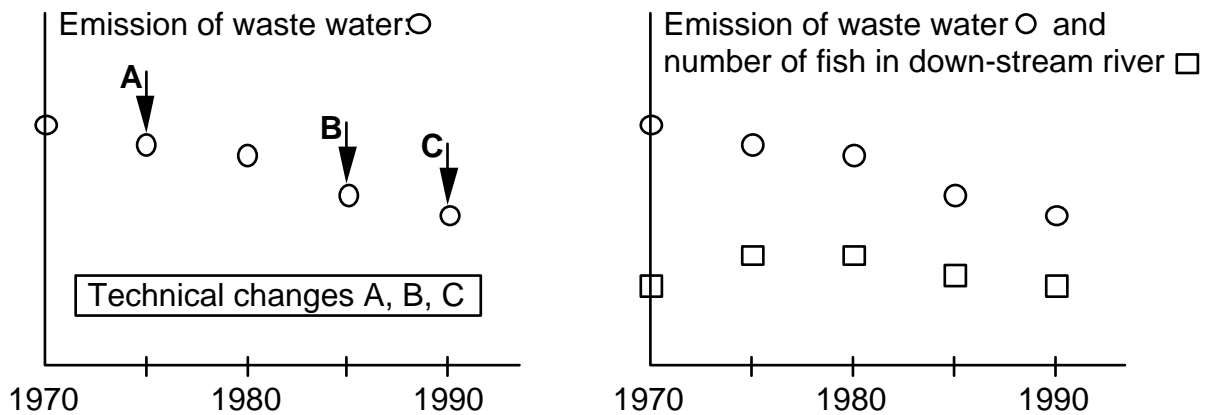
1970   1980   1990

Figure 4: The same emission of waste water as a technical indicator in the graph on
the left and as a environmental indicator in the graph on the right

categorisation of indicators, but rather, to observe which indicators are used in what areas of research and to observe where these indicators overlap. A recent example of such an overlap is in the publication *Environmental Indicators* (WRI, 1995) which discusses indicators to measure the impact of human activity on the natural environment *in the context of sustainable development*. On the other hand, a cursory overview of the literature leaves the impression that there are various scientific communities working on very similar problems but often without communicating across community borders.

1 Technical indicators: From Equipment to Systems

Indicators have always played an important role in all branches of engineering . The size of a thermal power plant is usually given by its maximum power output in Megawatts, its relative cost by Dollars per Kilowatts (of its maximum power output), its thermal efficiencies in BTUs or Megajoule input per Kilowatt-hour output or in percent and its emissions, for instance, in Grams of SO_2 per Kilowatt-hour output. Similarly, there are indicators for all kinds of properties of any kind of equipment: the speed of a computer, the storage capacity of its hard disk, the maximum sound output of a sound equipment, the power, maximum speed and specific fuel consumption of an automobile, and the like.

Historically, with the exception of a few visionaries[4], engineers applied indicators to isolated pieces of equipment. When in 1973 one of us (dsp) started to compute the cumulated energy requirement for producing an aluminium can, nobody in his firm, rich in tradition, had ever considered this question. The chemical engineers specialised in alumina production knew in which plant how much fuel was used to produce a ton of alumina (Al_2O_3) from bauxite and the engineers and managers of the electrolysis plants, knew precisely how many Kilowatt-hours of electricity (DC current) were necessary to produce a ton of aluminium from alumina[5], but nobody had looked beyond the boundary of their engineering expertise and added up the cumulated energy requirement of mining 4t of Bauxite, producing from it 2t of Al_2O_3 and out of that 1t of aluminium. Of course it was not quite as easy as that. Alumina plants use big quantities of caustic soda, which also are produced by one or the other energy intensive processes; the DC power used in the electrolysis plant does not occur in nature; the various plant have to be built, materials transported. In short, there is no end to the system that has to be analysed.

In recent years the energy accounting exercises and debates of the seventies have had a revival in the form of a more comprehensive approach, the life-cycle analysis (LCA) in which not only energy inputs are cumulated but all resource inputs, all emissions and waste streams. Note that LCA is mentioned purposefully here in this sub-section on technical indicators. LCA may borrow heavily from other disciplines (e.g. input/output methods from economics, various weighting schemes from environmental sciences) but the object of analysis is, in general, a technical system.

Unlike for a single piece of equipment, for a technical system the choice of indicators is often not straight forward. What are good indicators for the performance of an urban transport system? Speed, number of people it serves (actually or potentially), time lost in traffic congestion, size of labour market for the important employers in the city (number of workers having access to these

---

[4] Jevons studied in 1865 the over-all efficiency of using electricity from batteries charged by tidal power (Spreng 1988).

[6] In fact, electricity making up about a quarter of the production cost of this plant, the indicator Kilowatt-hour per ton of aluminium was and still is one of the most important figures of merit of such plant.

employers in less than , say, 60 minutes)[6]? What about indirect indicators does urban sprawl say much about the effectiveness of a transport system in the past 30 years? What does impervious surface coverage or transport-energy use per population say about the transport system?

The step from equipment to technical system is considerable. Researchers face many of the same problems constructing and interpreting indicators for more complex environmental and socio-economic systems.

Endless, tiring, but all the same useful in a number of ways were discussions on the energy requirement[7] and later LCA of packaging systems. The discussion did increase the general awareness of the environmental impact of packaging and in rare cases it did also help producers and buyers to make better systems choices. In some instances the energy requirement of packaging systems were the bases for legislative action[8]. Often analyses were also used as case studies for some ideological debate.

Also successful was the introduction of energy indicators in two other systems: buildings and vehicle fleets. In Switzerland the "Energiekennzahl" (energy indicator per se) is the fuel use (for heating purposes) per square meter of floor space. The Association of Architects and Engineers (SIA) has issued limit and target values for this index and it is generally believed, that the measure contributed considerably to halving this value for newly constructed buildings during the last 20 years. A newer indicator also refers to electricity use in commercial buildings. It is much more detailed and distinguishes both several uses (lighting, air conditioning etc.) and room types (offices, hall ways etc.). The indicator is expected to have a considerable impact on future energy use.

A recent world-wide web site billing illustrates the rapid development in this field: "The North American Energy Measurement and Verification Protocol (NEMVP) Web site offers access to a procedural document that allows buyers, sellers, and financiers of energy projects in buildings to quantify energy conservation measure

---

[6] Rémy Prud'homme, OEIL, IUP, Université de Paris XII, "Urban Transportation and Economic Development", CODATU VII, New Delhi, 1996

[7] Early contributions to the subject were B. Hannon "Bottles, Cans, Energy", Environment 14 (2), p. 11-21, 1972 and D. Spreng "Energetische Betrachtung des Verpackungsproblems ", NZZ, 14. Januar 1974

[8] In Oregon Aluminium cans were outlawed, in Germany milk was to be sold in re-usable bottles etc.

performance and energy savings. The NEMVP document provides a standard method for deciding cost-effective measurement and verification options for specific projects."

Another energy indicator with considerable impact on energy use[9] is the corporate average fuel economy (CAFE). This indicator refers not to one technical system, but to all automobiles sold by a particular car manufacturer.

Similarly, technical indicators can refer to all technical systems of a kind in one country. In many countries efforts have been undertaken to construct and report energy conservation indicators, which are designed to monitor national energy conservation policy[10]. These days a number of efforts are being pursued[11] to harmonise these endeavours internationally, so that it will be possible to make international comparisons of progress – or lack of progress – in energy conservation.

Similarly, indicators on a systems level, national or international level are in use for quantities other than energy.

2 Social indicators: Measuring the Quality of Life[12]

Much more than the engineering sciences, the social and political sciences are concerned with matters which do not easily lend themselves to quantification. We

---

[9] The impact of the US government-set CAFE goals is recognised by most analysts, but disputed by some (compare H. Dowlatabadi et al. "A free lunch at higher CAFE?", *Energy Policy,* Vol. 24, No. 3, pp. 253-264, 1996)

[10] Examples are: DOE/EIA, "Measuring Energy Efficiency in the United States' Economy: A Beginning", October 1995 and Natural Resources Canada, "Energy Efficiency Trends in Canada", April 1996

[11] N. Martin et al., "International Comparisons of Energy Efficiency", Workshop (March 6-9, 1994) -Proceedings, Lawrence Berkeley Laboratory, Berkeley California USA – "Methodologies for International Comparisons of Industrial Energy Efficiency", Workshop April 1-2 1996, Canadian Industry Energy End-use Data and Analysis Centre, Simon Fraser University, Burnaby, Canada

[12] As a basis for this section the following publications were used: R. Habich and H.H. Noll, "Soziale Indikatoren und Sozialberichterstattung – Internationale Erfahrungen und gegenwärtiger Forschungsstand", Bundesamt für Statistik, Bern 1994 and W. Zapf, "Sozialberichterstattung: Möglichkeiten und Probleme", Otto Schwarz & Co. Göttingen, 1976.

will limit this discussion[13] to the "social indicator movement" which aims at measuring the quality of life in nations and their various sub-groups.

Research to define, collect and report "social indicators" was initiated in the mid sixties by R.A. Bauer[14], who was at the time conducting a NASA study of social side-effects of space travel. There were earlier attempts and suggestions in this area, but the call for social indicators of Bauer and soon after that from M. Olson[15] came at a time in which the idea of a more active government and the scepticism of quantitative (monetary) growth coincided.

The boom period of the "social indicator movement" was the seventies. The OECD, the UN Social and Economic Council and the Conference of the European Statisticians initiated work of "more adequately monitoring and reporting social conditions and processes – implying a need to develop improved measures of the phenomena, together with expanded data collection capabilities"[16].

One distinguishes objective and subjective social indicators. Objective social indicators are statistical information (monetary and non-monetary) on the quality

---

[13] This section does not attempt to do justice to all social sciences. It will only point to the large effort made to measure well-being / the quality of life.

The indicators of the social and political sciences, which also include fields such as anthropology and psychology, are also related to such concepts as power, legitimacy, and conflict. These are very difficult to capture in indicators. Therefore, we often see in these fields the use of indirect indicators, of categorisations according to certain criteria, or of surveys.

Choucri (1974) categorises violent conflict in terms of "involvement of more than one nation" or "use of weapons" and "number of casualties" to express the intensity and frequency of a large collection of conflicts over a number of decades.

Surveys of happiness or of political legitimacy of politicians are well-known. The regular popularity polls of the US president and other politicians form one of the most important indicators of whether society agrees with the present political course of action. Popularity polls before elections have a similar indicator role. The results of a poll are qualitative even if they are expressed in percentage points: one can only answer "yea" or "nea" to the question "Do you agree?" but what, precisely, does *agree* mean?

One example of a creative, indirect social indicator is "literate life expectancy" suggested by Lutz (1995) to measure the welfare of populations using a composite index of health and education (the indicator aggregates literacy and life expectancy into an index).

[14] R.A. Bauer (ed.), "Social Indicators", Cambridge Mass., 1966

[15] M. Olson, "Toward a Social Report", US Department of Health Education and Welfare, 1969

[16] D.F. Johnston, "Some Reflections on the United States", *Journal of Public Policy,* Vol. 9, pp. 433-4436, 1990

of life of individuals, with respect to given social goals. Subjective social indicators leave the choice of what is desirable to the individual. Both types of indicators are used today in international social reporting.

In the eighties the enthusiasm for social indicators decreased, but one also could speak of a phase of consolidation in which some of the more solid endeavours became more mature and some of the others were discontinued. At present a rather well-established practice of reporting social conditions on national, international and sub national levels; and one observes a certain revival of social indicators in connection with the discussions of sustainable development.

Last year's list of social indicators of the working group "Social indicators and social reporting" of the European Communities Office of Statistics[17] comprises about 150 indicators in the following areas: education, social mobility, employment, income, consumption, housing, transport, leisure, social contacts, experience as a crime victim, participation in social life, health.

A mix of subjective and objective social indicators, on a small scale, are the neighbourhood indicators (Sawecki and Flynn, 1996). These are used by many small neighbourhoods to aid in planning and to assess the present policy to improve the quality of life in communities.

3   Environmental indicators: Pressure, State, Response

Much of nature exists outside of human intervention. The area of study has often been, particularly in biology and ecology, "pristine" nature. The study of the pristine state shows the general rules, or laws, governing the natural system. Humans can cause much interference and change in the pristine state. It then becomes more difficult to study the system's own rules.

One old thread of the study of the natural environment has been a taxonomy, the listing of natural species of plants, animals, soils and minerals of different types. Similarly descriptive of an existing state has been the search for an understanding of how nature functions. The taxonomy and the understanding of functions have led to indicators which either show differences or functionality. Indicators of the natural state are, for example: for soils -- the moisture content, the pH level, the soil depth; for climate -- average air and water temperatures, average rainfall,

---

[17]   Statistisches Amt der Europäischen Gemeinschaften, DOC E2/IS/2/95

periodicity of rainfall; for ecosystem richness -- the biodiversity, or, number of species per square kilometre; for water -- the oxygen content; for measure of adaptation -- number of surviving offspring. All of these indicators can be used to study the pristine state and also to measure how human interaction causes changes from that state.

Recently, the study of the effects of human intervention have become more important. Many of these indicators are composite indices made of many indicators, or ratios. Examples of composite indices used by the Netherlands Government (published in WRI, 1995) are
- contribution to climate change
- contribution to ozone depletion
- acidification equivalent per hectare
- toxic dispersion equivalents
- eutrophication equivalents
- solid waste equivalents.

Note that all of these composite indices are changed into units or equivalents. This is because most of environmental impacts are caused by a multitude of waste products, which each have a different effect on the environment. These differences are weighted in the composite indices.

Other indicators which are used in the WRI publication are ratios. For example, "resource depletion / gross fixed capital formation" which shows how much the human economy is building up in productive potential in *exchange* for using natural resources. In a sustainability sense, capital formation should compensate for the natural resource depletion.

Another type of the assessment of the extent to which human intervention affects the natural state, are models comparing the original and the altered state. Examples of such models are:

- stress models
  - PSR model (pressure, state, response-model)
  - others

- actor-acceptor model

- man-environment-man model

- space-ship-earth models
  - comparisons with some assumed pristine state
  - critical levels, critical loads and critical structural changes
  - ecological carrying-capacity model, including foot-print model.

Stress models and actor-acceptor models suggest causality, but are very forgiving to non-causality. This, probably, is the secret of their success. In international organisations, the PSR model is used most frequently (for references, see section 5). Examples of indicators referring to the PSR model are, for instance, for forests,

- *pressures:* deforestation rate (km^2/annum), annual round wood production (m^3)

- *states:* change in biomass (%), timber stocks (m^3), forest area (km^2), forest inventory

- *response:* reforestation rate (km^2/annum), protected forest area as % of total land area.

There are stress models that are similar to PSR models but include only two of the three types of indicators, namely stresses (Pressures) and responses. Another model includes four rather than three types, this is the pressure, state, impact, response model (used by SCOPE) . Here, causality is forcefully and optimistically introduced.

The difference between stress models and actor-acceptor model is the position of man in the quasi-causal chain. In the stress models "pressure", "stress", "driving force" always starts out with human activities, where as in the actor-acceptor model man as well as nature can be both actors and acceptors.

The man-environment-man model[18] may be the model with the soundest theoretical base. Here, man's impact on the environment is only of interest in so far as this impact produces a change in the environment, which in turn impacts – sooner or later – back on man. This anthropocentric view corresponds well with Western thought[19] and is precise. How could we devise indicator systems on changes in nature we do not even see or look for? But since we very often do not know

---

[18] R. Bolleyer and W. Rademacher, "Aufbau der Umweltökonomischen Gesamtrechnung: Ein Bericht aus der Werkstatt", Wirtschaft und Statistik 2, S. 138-152, 1993

[19] Hans-Peter Schreiber: Ökologische Ethik", Talk given at ETH Zurich, 20 May 1996, see also D. Spreng, "Weiss es die Natur am besten?", *Tages-Anzeiger Magazin*, 11. Oktober 1980

whether and how changes in nature will affect us, this model is more of conceptual than of practical value. Even from a purely anthropocentric perspective it may be wise not only to preserve resources and limit environmental damage, but also to preserve biodiversity. An anthropocentric view is (hopefully) not identical to an economic perspective. Even if a high biodiversity may have no high economic value, it may have a high scientific, cultural, aesthetic or psychological value – it might be psychologically damaging to mankind to disrespect fellow creatures.

Under the rubric of space-ship-earth models we group a number of very different models. All have to do with the easily communicable idea concepts of "limits to growth" or "space-ship earth". Comparisons with some assumed (eternally constant!) pristine state lack scientific foundation but play a big role in people's thinking, be they (natural) scientists[20] or lay people. The concept of critical levels, critical loads and critical structural changes (German "Umweltgutachten 1994") is scientifically much more sound but puts the difficult step on the determination of these critical levels. One pragmatic way to deal with it is to compare actual pressures and states with environmental regulation (as suggested in Figure 3).

4 Economic indicators: Towards a SNA[21] that "takes nature into account[22]"[23]

Economic indicators are used to measure the present state of the market or of companies (performance indicators) or to indicate a future direction (leading indicators). A selection of traditional economic indicators is given below.

Macro-economics uses indicators such as:

- GDP, the sum of exchange value of the market, regardless of whether the value is to pay for actual new goods, or to clean up environmental damage. Of particular interest are the growth rate of GDP and GDP per capita. GDP was established as an indicator in the 1930s in an effort to summarise national

---

[20] Wagner, EAWAG Dübendorf, studied researcher's personal concepts of Sustainability, 1996

[21] System of National Accounts

[22] "Club of Rome"-Report: W. van Dieren (Ed.) "Taking Nature into Account", Springer New York, 1995
"Mit der Natur rechnen", Birkhäuser Basel, 1995

[23] This section needs further development.

accounts. At that time, it grew out of a lengthy discussion (similar to the present one on sustainability indicators?).

- National accounts production per economic sector, investment in capital, devaluation of capital, national debt, money exchange rates.

- GDP and national accounts are published in national yearbooks and also in international annual compilations such as the World Bank Tables, World Bank national accounts, and the IMF debt tables.

- Employment, the number of people in the economy who are engaged in work (usually meaning paid work). Of particular interest is the unemployment rate, a ratio of the number of people who are seeking work and the number who have work. Employment statistics are published in national yearbooks and in international compilations by, for example, the International Labour Organisation (ILO).

- Dow-Jones index or other aggregated stock market indices.

Micro-economic indicators include:

- Profit flow, stock value, balance sheets, cash reserves, inventories. Such indicators are found in the annual company reports. Stock values can be found in daily newspapers, such as the Financial Times, or the New York Times.

- Characteristic of virtually all economic indicators is that they are expressed in money terms, employment being the notable exception.

The most powerful economic indicator today is certainly GDP or GNP. This is the sum of the exchange value of the market, regardless of whether the value is to pay for actual new goods or to clean up damage to the environment or human health. GDP was established as an indicator in the 1930s in an effort to summarise national accounts. At that time, it grew out of a lengthy discussion. It is doubtful that the original proponents of the indicator meant it to become as powerful as it is today. GDP, and the national accounts which are its basis, are published in national yearbooks, and also in international compilations such as the World Bank Tables, World Bank national accounts, and the IMF debt tables. Some of the data in the national accounts themselves are also important indicators, such as, investment in capital, devaluation of capital, national debt, the ratio of dept to GDP, money exchange rates, and interest rates.

Employment indicators are examples of non-monetary economic indicators. The number of employed people usually refers to those engaged in the market for remuneration. Of particular interest is the unemployment rate: the number of people who do not have work, divided by the total labour force. Employment statistics are published in national yearbooks, and in , for example, international compilations by the International Labour Organisation (ILO). Another labour-related index is the Gini coefficient, named after its Italian inventor, which measures income distribution in a given region. This indicator is not very widely published.

Of particular interest is the Dow Jones Index and its international counterparts. The Dow Jones Index is a composite number taken from a selection of the perceived most important stocks. Next to GDP, it is probably the most powerful short-run indicator of economic value, or rather, of stockbrokers' perception of companies economic value.

At the base of the stockbrokers perceptions are micro-economic indicators published by individual companies. Profit flow, balance sheets, cash reserves, inventories are important numbers in such publications.

Uneasiness with the traditional economic measures is not new. The social indicator movement owes it existence partly to this uneasiness and dissatisfaction. Similarly, energy accounting was seen by some of its proponents[24] as a way to improve on monetary accounting (possibly with the distant aim of replacing it!). Dissatisfaction with the limited relevance of traditional monetary accounts, particularly with the poor correlation of well-being and GNP, exists also among economists. In the 1960s the monetary value of landscapes was computed in connection with hydro-power schemes. Already in the 1970s a few economists attempted to include environmental factors, particularly resource use and later also waste streams, in national accounts. Since 1993 there has been the UN-Handbook on Integrated Environmental and Economic Accounting[25].

The latest "Club of Rome"-Report includes a number of recommendations how to use this UN-Handbook and how to improve it. One principal recommendation is not to use monetary accounts only, but to complement monetary accounts with

[24] e.g. H. Odum, "Environment, Power and Society", John Weily, 1971

[25] UN-Handbook on Integrated Environmental and Economic Accounting, Handbook of National Accounting, Studies and Methods, Series F, Nr. 61, Sales Nr. E. 93.XVII.12, New York, 1993

non-monetary indicators – even if the monetary indicators are designed "to take nature into account".

The economic tradition has, in the past decades, shown an increasing interest to include the environment in economic theory and research. Thus far, in economic theory, this has led to models which include the trade-offs between economic growth and natural resources (for example, Nordhaus, 1991; Pindyck, 1995, Sieber, 1987). In these models the indicator which is to be maximised is the total consumer utility in a period of time. Unfortunately, the difficulty of measuring consumer utility reduces the usefulness of such indicators.

Recently, a group of researchers who call themselves *ecological economists* has widened the economic indicator list considerably. As these economists are specifically concerned with sustainable development, their indicators are discussed in the next section.

5   Sustainability indicators

Sustainable development has to do with finding the proper balance between economic growth and conservation, equity within and between generations, and other trade-offs. One of the goals of this project is to show which indicators or groups of indicators are more apt than others to monitor and communicate chances for and threats to sustainable development (see page 7).

Sustainable development as a concept has become popular in the past decade, particularly since the publication of *Our Common Future* (1987).[26] The definition used in that report is as follows:

> The ability of humanity to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable development is not a fixed state of harmony, but rather a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional changes are made consistent with future as well as present needs. (*Our Common Future* ,1987).

---

[26]   World Commission on Environment and Development. *Our Common Future*. Oxford: Oxford University Press, 1987.

Of course this report was not the first to express explicit concern with the ability of humans to provide a durable future to the next generations. Texts from ancient societies through the birth of industrial society in Europe in the 18th century (Malthus, Mill) express concerns on the future of society and the environment. In the beginning of the 1970s, the Club of Rome published a series of influential reports on the dynamic interaction between human economic activity, environmental resources, and welfare (the most famous is doubtless *Limits to Growth*, Meadows et.al., 1972). Another well-known report from that period on the future of human society is Lester Brown's *Report to the President.*

However, since *Our Common Future* coined the term *sustainable development*, there has been a focus of research around this term.

As it is fairly new, there has been much effort at first to define sustainable development. A selection of definitions can be found in Murcott, 1995.
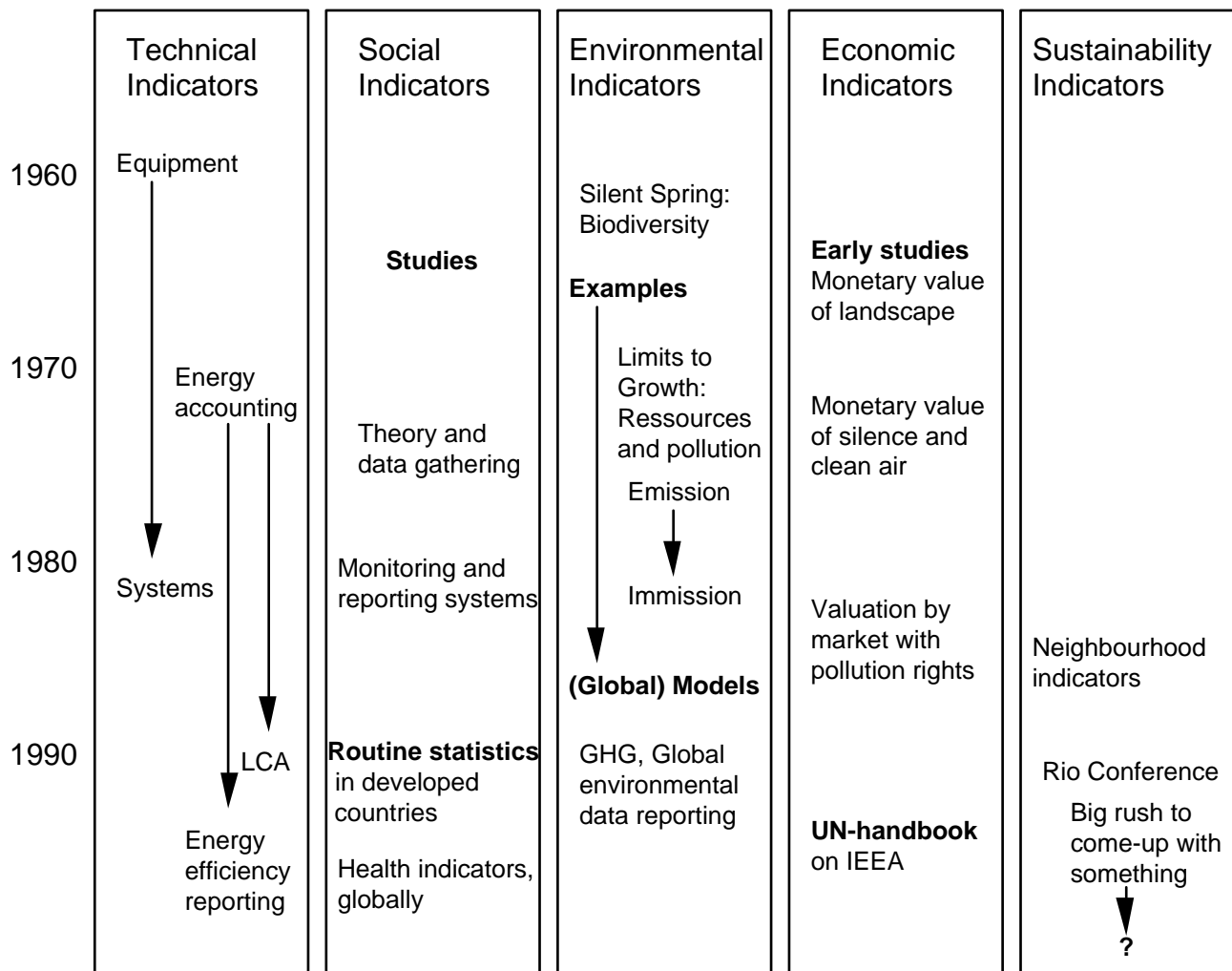
Connected to the definitions and leading to indicators is the work which sets down criteria and principles for sustainable development. *Our Common Future* names four criteria:
- inter-generational equity
- intra-generational equity
- public participation
- environmental protection integral to economic development.

Herman Daly provides three operational principles of sustainable development: renewable resources shall be used only at the rate they can be naturally replaced; nonrenewable resources shall be used only at the rate renewable substitutes are found; the emission rates of pollutants shall be no greater than the ability of the natural system to assimilate them.

History of indicator development in four disciplines in relation to their use as sustainability indicators

	Technical Indicators	Social Indicators	Environmental Indicators	Economic Indicators	Sustainability Indicators
1960	Equipment		Silent Spring: Biodiversity	**Early studies** Monetary value of landscape	
		Studies	**Examples**		
1970	Energy accounting	Theory and data gathering	Limits to Growth: Ressources and pollution Emission	Monetary value of silence and clean air	
1980	Systems	Monitoring and reporting systems	Immission	Valuation by market with pollution rights	Neighbourhood indicators
1990	LCA Energy efficiency reporting	**Routine statistics** in developed countries Health indicators, globally	**(Global) Models** GHG, Global environmental data reporting	**UN-handbook** on IEEA	Rio Conference Big rush to come-up with something ?

Opschoor and Costanza clarified thresholds implied by Daly's principles: There is a whole range of possible criteria for formulating thresholds. At the one extreme there is the zero pressure or some approximation of that based on an historical reference (e.g. species diversity or acidification levels in 1850 or any other year indicative of the pre-industrial situation). At the other, there is the zero-effect level in terms of known manifest impacts on the relevant receptor. Intermediate positions can be taken within the range between *zero-pressure* and *zero-effect.* This is only a small selection of the many texts with criteria and principles.

A third tier of sustainability research which has run parallel to the first two but follows from their results, is the search for sustainability indicators. As implied by

the definitions and criteria, the indicators must cover a wide range of quality, quantity, and durability. Indicators of sustainability[27] therefore should say something about

- the quantity of our activities to provide for human needs -- this is related to the economic market;

- the quality of the results -- what is the quality of life?;

- how much longer we can engage in these activities, assuming unsustainable use of natural capital, how much longer will the stock of that capital last at the present rate of usage or:

- are we finding alternatives at a sufficient rate?

The efforts to find sustainability indicators range from a selection of particularly useful indicators from the set of those which are already being collected and published, to developing completely new indicators.

Sustainability indicators have both their methodological and historical roots in the indicators we have discussed in the four previous sections. The figure on the previous page illustrates this.

A selection of proposals for compounded indices of sustainable development are:

- The human development index (HDI) compiled annually by UNDP which includes GDP per capita, literacy and life-expectancy.

- The Net National Product and similar indices which subtract the use of natural capital, clean-up activities from environmental degradation, and catastrophes (but not human violence, so far) from GDP have received much attention at

---

[27] In many cases "sustainability indicators", particularly if they refer to global sustainability, are nothing more than environmental indicators, or sometimes a simple pasting together of environmental and economic indicators. This does not merit a new name. However, as illustrated in Figure 4, one indicator, say a particular water-pollution emission, can serve both those with a strong interest in the affected environment and those with a strong interest in the technical system responsible for this emission. In the same way environmental indicators can very well serve as part of the information one needs to develop the concept of sustainable development.

If an environmental pressure-indicator is also
• a good indicator of economic growth and
• can, at the same time, serve as an environmental state-indicator
we have more than just a usual environmental indicator. Both indicators proposed for detailed study during the workshops, energy use and impervious surface coverage are candidates for indicators that exceed the boundaries of traditional categories (sections 1 to 4).

the World Bank (El Serafy, and Seragelden), and among ecological economists (Perring, Costanza, Hueting and others).

- Ecological Footprint (Wackernagel and Rees, 1996) measures the amount of land which a country or region actually appropriates with its activities. For example, the Netherlands uses not only its own land area, but also 14 times as much spread around the world where the products that it imports are produced. Net Primary Production (NPP) appropriation (Vitousek, 1986) measures the portions human societies use out of the total amount of solar energy captured by green plants.

- Index of Sustainable Economic Welfare (ISEW) and the Genuine Progress Indicator (GPI) subtract pollution clean-up and add unpaid valuable work such as housework.

- Literate Life Expectancy (Lutz, 1995), a composite index of health and education in the population, regarded by some to be the most important indicator of welfare.

Integration into dynamic or theoretical thinking.

The inclusion of time and linkages and the development of indicator frameworks and entirely new indicators:

- One such approach is to arrange indicators into pressure, state, impact, response (PSIR) indicators for any particular sustainability problem. This is the approach proposed by the Worldwatch Institute, and a similar approach is followed by the UN's group, SCOPE.

- Daly proposes to arrange our position in the world according to a triangle whose base is ultimate means (natural capital), middle is intermediate means (man-made capital) and intermediate ends (consumption and human capital), and whose top is ultimate ends (fulfilment, harmony, self-realisation, love). Economics includes intermediate means and ends. To speak of development, one must include the ultimate ends, and to be sustainable, one must include the ultimate means. Sustainability indicators measure how much of the ultimate means are being exhausted and how much regenerated; and development indicators are qualitative.

- The INRIC group discusses the above and also using human capital, social capital, and natural capital besides man-made capital as measures of

sustainability. Capital stocks are a measure of real, accumulated wealth or welfare. They also discuss the use of dynamic leading indicators – these measure whether natural capital or human capital is in the process of being used up – e.g. an increase in the effort necessary to catch a ton of fish is a leading indicator that fish stocks are declining, long before they have gone to zero. Generally, ratios are preferable to static measures (e.g. ratio of present use to remaining reserves)

- *In Search of Indicators of Sustainable Development* (1991) includes chapters by Opschoor and Reijnders which suggest making sustainability indicators over time (e.g. the rate at which natural species currently die out is 106 times the natural origin of species). Ten Brink suggests an index to measure the distance current ecosystems are from the desired state and an aggregation over a large region or nation, an "ecological Dow-Jones index".

The footprint method has recently become very popular in Europe. Its champion comes originally from ETH[28] and is now Vancouver. It is the basis of a large international effort by the "Friends of the Earth" to produce reports with the titles such as "Zukunftsfähiges Deutschland", "Nachhaltige Schweiz" etc. In these studies all environmental insults and resource consumption are transformed into square meters of land. To execute these transformations, rather arbitrary assumptions on "sustainable technologies" – such as solar energy and biomass for energy production – are made. The result for Switzerland is that its foot print is 6.5 times larger than all of Switzerland (die Schweiz lebt auf viel zu grossem Fuss). The footprint idea is a popularised version of the ecological carrying-capacity model conceived of and tested in Holland[29].

---

[28] M. Wackernagel et al., "How big is our Ecological Footprint? A Handbook for Estimating a Community's Appropriated Carrying Capacity", Task Force on Planning Healthy and Sustainable Communities, University of Columbia, Vancouver, 1993

[29] R.A.P.M. Weterings, J.B. Opschoor, "The Ecocapacity as a Challenge to Technological Development", Rijkswijk: RMNO, Advisory Council for Research on Nature and Environment, 1992