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Abstract: Explores the concept of sustainability and the derivation of sustainability indicators. Two general conceptions of sustainability; Criteria proposed for indicators; Indicators developed in the area of sustainability; Development of indicators in the national and international levels; Development of sustainability indicators in Scotland. INSETS: Frameworks for sustainability indicator sets; Selected indicators; Sustainability indices; The sustainability indicator set for FIFE, Scotland.

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WHAT DOES SUSTAINABILITY REALLY MEAN? THE SEARCH FOR USEFUL INDICATORS

Four years ago, the town of-North Andover. Massachusetts, began grappling with an issue common to many communities: how to set the price for the water it supplies to residents. The town was fortunate in having a good source of clean water in a municipally-owned lake. But resident water bills had been rising steadily for several years, and many were unhappy about it. One reason for these increases was the town's new $20 million treatment plant. But town authorities had also set the water rates so as to generate a small profit--a fact that spawned a vigorous debate among residents. Some approved of this strategy, while others felt that the town should sell water at cost, and still others wanted to subsidize the water used by low-income residents.

Framing the debate solely in terms of dollars allowed a very important fact to go unnoticed however: North Andover's water use was close to exceeding the available supply. the lake's "safe yield" (the amount of water that can dependably be withdrawn even in times of drought) was estimated to be 3.4 million gallon per day by 2000. North Andover has still not solved its water problem, but it has shifted the focus of the debate from revenues to sustainability--a change that has had some marked consequences. The town's community development director has incorporated a measure of safe yield per person into projections of the town's growth. The town manager has proposed a conservation-oriented rate structure that would charge people higher-rates the more water they use. And a developer is talking about ways to reduce the use of in-ground lawn sprinklers one of the principal causes of increasing demand for water.

Both water revenues (the initial focus of the debate) and consumption relative to the safe yield (the current focus) are indicators of community well-being. The first pertains to the town's financial position, the second to its use of key resource. The crucial difference between them is that the revenue indicator would eventually fail--at some point, water shortages would force the town water rates to bring demand into line with supply, restricting water use, purchasing additional water elsewhere, or some other measure.

The situation in North Andover offers a concrete example of the need to ensure that human activities are sustainable. Although the importance of sustainability is gaining acceptance in many parts of the world, furthering it poses a serious challenge to decision makers because there is no generally accepted definition of the term. Even those who support this concept disagree on its precise meaning, while those who do not support it argue that it has no meaning at all.[1] And just as there is no agreement on the meaning of sustainability, so there is no widely recognized way to measure it. As a result, researchers and organizations have been left to their own devices in formulating specific (usually qualitative) indicators of sustainability and progress toward that goal. These efforts may provide useful guides for policy in the future. But they are already significant because they provide a number of concrete definitions of sustainability--indicating that although the concept means different things to different people, it is far from meaningless.

This article explores the concept of sustainability and the derivation of sustainability indicators, focusing on some of the more prominent efforts in this area to date. There is still a long way to go to reach consensus on how to measure sustainability. However, the ongoing efforts of many organizations (ranging from local, grassroots initiatives to those of global institutions) are helping to change sustainability from a buzz word to a meaningful concept that is understandable to the lay public and that may become useful for decisionmaking.

The Concept of Sustainability

There are two general conceptions of sustainability, which are often seen as being in conflict. Concerns about environmental degradation and the Earth's carrying capacity[2] have led to what might be called the critical limits view of sustainability. This view focuses on natural assets such as the ozone layer, fertile soil, and healthy wetlands, which provide services people rely on to live and which we do not know how to replace. Together, such assets constitute ecosystems that are essential to human well-being. This implies that we must preserve these ecosystems and respect the limits that they impose on the number of people in the world and their mode of living. The competing objectives view of sustainability, on the other hand, focuses on balancing social, economic, and ecological goals. It thus aims at meeting a broad range of human needs and aspirations, including health, literacy, and political freedom as well as purely material needs.[3]

These concepts differ in two important ways. First, the idea of resource limits is central to the critical limits view but entirely absent from the competing objectives view. Second, the critical limits view has a much narrower scope. It is also said to be more objective, but that assertion is questionable. Because the number of humans that the Earth can support is not readily determinable, it is not always clear which assets are critical and which are not. For example, although biodiversity is a necessary component of a healthy wetland ecosystem, it is not always clear how important each individual species is. For this reason, it is virtually impossible to ascertain the amount of resources that humans require without making some subjective judgments.

Each view, however, is very concerned about equity, both within and between generations. Intergenerational equity, of course, entails leaving future generations an ecologically viable planet with abundant resources, while intragenerational equity entails distributing the environmental costs and benefits fairly among people living now. Both forms of equity are based in part on concerns about the morality of some people living well at the expense of others. A more; pragmatic concern is that the poverty resulting from inequitable resource distribution leads to the degradation of ecosystems.[4] The destruction of local ecosystems can, of course, have global effects. For example, the global climate system depends in part

on the role of rainforests, which are often clearcut due to local pressure for jobs and income. Such changes can lead to international--and possibly violent-conflicts over scarce resources, such as the recent conflict between Canada and the United States over fishing rights and disputes over water rights worldwide.

Although there is no agreement on the precise meaning of sustainability, a good working definition--one that incorporates elements of both views-might be the following: "improving the quality of human life while living within the carrying capacity of supporting ecosystems."[5] Whatever definition one choses, there is widespread agreement that sustainability is important and that indicators to measure progress toward it are needed.

Indicators of Sustainability

In general, an indicator is something that provides useful information about a physical, social, or economic system, usually in numerical terms.[6] Indicators can be used to describe the state of the system, to detect changes in it, and to show cause-and-effect relationships. For instance, the level of water in a reservoir is a state, drawdowns represent a change in that state, and comparisons of these variables over time can reveal cause-and-effect relationships such as the impact of conservation policies on water usage. Indicators thus supplement other information that we have (such as that from theories), giving us more complete pictures of the systems in question.

The choice of a particular indicator is guided by two considerations: what one wishes to know and how the information will be used. Scientists and analysts are generally interested in seeing the raw data and interpreting it themselves.[7] Policymakers are more interested in summary information that is clearly related to policy objectives, evaluation criteria, and targets; they usually do not want to perform much analysis themselves, although they may be interested in how it is done. And members of the public, who tend to lack an analytical perspective, often just want simple, clear, unambiguous messages. Regardless of the level of detail, however, there are certain characteristics that every good indicator will have, such as relevancy and the use of reliable data.

One point should be stressed, however: Although a great deal has been written about indicators in general, much less work has been done on sustainability indicators per se. The criteria that have been proposed for such indicators suggest that they should focus on a fairly broad range of concerns, such as furthering inter- and intragenerational equity; not exceeding the carrying capacity of natural resources and ecosystems; reducing the impact that human activities have on the ***environment*** (particularly the rates at which renewable and nonrenewable resources are used); integrating long-term economic, social, and environmental goals; and preserving biological, cultural, and economic diversity.[8] More research is needed in this area, however.

In the area of sustainability, a number of different indicators have been developed. These indicators vary considerably, depending on the underlying view of sustainability they embody, the organizing framework they employ, and the interests and goals of their creators (see the box on page 8 for a description of the frameworks most commonly used for indicators). Specific examples include energy use and emissions of greenhouse gases (total and per capita); the percent of harvested forest that is successfully replanted; environmentally adjusted measurements of economic activity; the hours of work (at the average wage) that are required to satisfy basic needs; the income disparity between the top and bottom segments of the population; and the number of college graduates who are able to return home and find appropriate employment.

Indicators are generally reported in one of three ways: individually, as part of a set, or in the form of a composite index that combines various individual indicators into a single number. As a rule, individual indicators are of limited use--a balanced set of indicators is needed to adequately represent a complex system. A well-chosen suite of indicators can also be very educational, particularly for the lay public. Then too, a single, aggregated number can be very useful in communicating information to the public and decision makers, although the appropriate methods to use in achieving such aggregation remain very controversial. (See the box on page 9 for examples of the indicators identified by the United Nations Commission on Sustainable Development and the box on page 26 for further details on aggregation.)

The organizations that are developing sustainability indicators range from the international to the very local, from corporations to national and municipal governments. Not only have they produced different kinds of indicators, they have used very different processes to do so. Indeed, many participants and observers note that the process of developing a sustainability indicator set is as valuable as the set of indicators that results. The process is considered so important, in fact, that there are now guides on how to develop sustainability indicators.[9]

A good example of the advice being offered is the Bellagio principles, which were developed by an international group of researchers and practitioners in 1996.[10] These principles are built on four basic concepts: First, those developing a set of indicators must have a vision of sustainability that is appropriate for the particular place and people involved. Second, the indicators should reflect a holistic view of the linkages between the economic, environmental, and social aspects of development, they should consider both inter- and intragenerational equity, and they should consider the ecological conditions that life depends on and have sufficient scope to address distant effects while still having practical application. Third, the process of developing indicators should be open, inclusive, and take advantage of existing techniques and technologies for effective communication. And fourth, the developers need to conduct ongoing assessments of the quality of the indicators in the set. Although the exact process has varied, many of the sustainability indicator projects undertaken to date have relied on these general principles.

Current Efforts

National and International

Sustainability indicators are being developed at the national level in many countries, although with different levels of effort and different degrees of sophistication. For most, Agenda 21--the principal document signed at the 1992 Earth Summit--provides important motivations and guidance.[11] International efforts to develop sustainability indicator sets generally have two objectives: coordinating national and subnational efforts and evaluating global-scale processes and effects. Most of these efforts are conducted by groups of government employees (often from different departments) assisted by outside experts.

Canada was one of the earliest countries to attempt to measure sustainability, having started an environmental indicators program in 1989 and published sustainability plans as early as 1993. Sustainability indicators are now used routinely by governmental bodies in Canada from the local to the national level. The national-level indicators are organized by topic; there are also sectoral indicators for the forestry sector.

Within the U.S. government, efforts to develop sustainability indicators are guided by the report of the President's Council on Sustainable Development, a panel of business, government, and environmental leaders that met for two years to attempt to identify what

sustainability meant for a broad range of issues. Their recommendations emphasize improving management practices to reduce the cost and red tape associated with environmental protection; increasing public participation in the development of environmental policy; improving social and economic opportunities; and promoting intergenerational equity.[12] An Interagency Working Group on Sustainable Development Indicators that has been at work since 1994 recently proposed an indicator set that includes 32 indicators.[13] The overall framework includes three concepts: endowments (the resources, assets, and conditions--economic, environmental, and social--that are inherited from past generations and passed on to future generations); current outputs (the goods, services, and experiences that the current generation enjoys); and processes (activities that use endowments to produce current outputs). Although this framework is partially topic-based, it also attempts to identify pressures on the ***environment*** as well as the effects of policy responses. The working group states explicitly that the framework is not intended to include criteria for selecting indicators; instead, a collaborative process that "allows wide participation and achieves broad consensus" is to be used. As a result, some of the indicators that have been proposed, such as gross domestic product, have the characteristics of good indicators but are not true sustainability indicators.

In addition to this effort, several federal agencies have launched sustainability indicator programs, notably the U.S. Forest Service and the Environmental Protection Agency (EPA). The Forest Service has held a series of roundtables with forest-based communities and other federal agencies on sustainable forestry management and has begun to produce sustainability indicators, but it is not clear whether these efforts have led to changes in policy.[14] Not surprisingly, EPA has many programs related to sustainability indicators at both the national and regional levels.[15] These too are mostly in the development stage and have not led to major changes in policy. EPA's Office of Sustainable Ecosystems and Communities has even developed a training program for community leaders who would like to formulate sustainability indicator sets for their own purposes.[16]

Many European countries have undertaken extensive efforts to develop sustainability indicators as pan of their response to Agenda 21.[17] Some of these have been conducted by governments, but many are the work of research institutes and environmental organizations such as the European chapters of Friends of the Earth (FOE).[18] In 1995, FOE launched a "Sustainable Europe" campaign that has produced sustainability indicator sets for several different countries, including those usually considered green (Austria, Germany, the Netherlands, Norway, and Finland) plus Scotland.[19] The FOE approach uses the concept of "environmental space"--a critical limits approach organized by topics.

Although European efforts generally take the critical limits view of sustainability, they do tend to acknowledge the equity implications of the very large differences in standards of living in industrialized and nonindustrialized countries and they clearly show an appreciation for the value-laden nature of choosing sustainability indicators. Because FOE explicitly describes the choice of indicators and the determination of numerical targets as requiring both scientific information and value judgments, these endeavors are best described as social processes. It is somewhat surprising, therefore, to observe relatively few social and economic indicators in some of the European sustainability indicator efforts.

During the last several years, the European Union (EU) has been moving towards the adoption of sustainability as an important goal, and several member states have been pressuring the European Commission to develop sustainability indicators. Currently, the EU has an Environmental Pressure Indices program under way and is making an effort to use a set of indicators developed by the United Nations Commission on Sustainable Development. Although the recently established European Environmental Agency is largely

a data-gathering organization at present, it may play a larger role in implementing sustainability indicators in the future.

Most developing nations lag behind in the implementation of sustainability indicators, though Costa Rica and the Philippines stand out as good examples of countries that have taken the first steps.[20] Most poor countries see economic development as their primary objective, and it is only in the last decade that their governments have become concerned about environmental issues like pollution. The sustainability indicator programs that do exist in such countries tend to be fairly small efforts that are usually conducted with outside funding (often from an international development agency). And poor nations face a serious challenge in developing sustainability indicators owing to the lack of reliable and comprehensive data, among other factors.

Local

Local efforts to develop sustainability indicators (usually indicator sets) have employed widely varying definitions of sustainability. While some attempt to measure sustainability per se, others focus on quality of life or the "state of the community." Most of these efforts, however, reflect the competing objectives view of sustainability, although the most thoughtful ones also focus on respecting biogeophysical limits.[21]

Perhaps the best-known such effort (at least in the United States) is the indicator set formulated by residents of Seattle, Washington.[22] This effort began in 1990, following a conference sponsored by the Global Tomorrow Coalition. It has since produced a series of reports on indicators and trends, the most recent being released in April of this year. The process entailed extensive public meetings over a period of two years, aided by a small amount of grant money for organizational and communications activities.

The definition of sustainability used by this community is "long-term health and vitality--cultural, economic, environmental, and social."[23] The indicator set includes 40 individual indicators grouped according to five main topics: the ***environment***, population and resources, the economy, youth and education, and health and community. Five criteria were used to identify suitable indicators. Each indicator had to be a bellwether of sustainability, that is, it had to "reflect something basic and fundamental to the long-term cultural, economic, environmental, or social health of a community over generations." It also had to be accepted by the community; attractive to local media; statistically measurable; and logically or scientifically defensible.

Although not stated specifically in the criteria, the ability of an indicator to highlight the linkages between different parts of the community was another selection factor. The indicators used by Sustainable Seattle include the number of salmon returning to spawn (compared with a 1978 baseline); the annual per capita number of vehicle miles traveled and gallons of gasoline consumed; the number of hours of work at the average wage needed to pay for basic needs; and total and per capita water consumption.

These indicators are maintained by a volunteer organization housed at the Seattle Metrocenter YMCA. Tracking and publishing the indicators from 1993 to the present has involved hundreds of area residents (more than 250 worked on the 1998 report). The main purpose of this effort is to provide education and outreach to the community on issues related to sustainability. Because Sustainable Seattle is not affiliated with any governmental organization, its reports are not used directly in policy making, though they have influenced a number of projects undertaken by area governments.[24]

Another good example of a local indicator effort comes from Fife, Scotland.[25] This community used three criteria for selecting indicators: the effect of the activities in question on future generations; the full environmental cost of those activities; and the fairness of the resulting distribution of resources and services. In addition, the entire community was encouraged to participate in the decisionmaking process. The resulting indicator set includes 20 indicators framed in terms of four topics (see the box on page 29). This set, which is typical of local efforts, is fairly balanced. However, it has at least one drawback that is common to such efforts: It does not provide adequate information for decisionmaking. For instance, the indicator "tons of fish landed at Fife ports" does not indicate the optimal level of such landings (a larger catch would provide immediate economic benefits but could also entail greater long-term harm to the ***environment***). To be sure, the accompanying text notes some of the issues underlying this indicator, such as the long-term decline of fisheries, the effect of competition from large boats on small boat operators and fishing villages, and the amount of nonrenewable energy that is expended in catching fish compared with the energy gained by eating it. But it merely raises a red flag without necessarily showing which way to go.

Three general observations can be made about the formulation of sustainability indicators at the local level. First, whatever indicators are selected, the selection process is valuable because it focuses attention on the issue of sustainability. Most of the communities that have adopted indicators began with no more than a rudimentary notion of this concept and its implications for community life. However, the lengthy and sometimes difficult process of selecting indicators forced them to examine not only the environmental, economic, and social conditions at issue but their values as well, As a result, many people have come away with a more intuitive understanding of sustainability and what it means for them as individuals and as a community.

Second, most of the local sustainability indicator initiatives in the United States are grassroots responses to local concerns and do not refer to Agenda 21 or other concepts developed at the international level. Thus, even though those leading such efforts are familiar with international work (and most U.S. efforts are consistent with the broad outline of sustainability indicators articulated in international documents), home-grown practices and techniques developed by peers tend to dominate U.S. efforts. In a word, there seems to be no attempt to connect local sustainability indicators to anything at a larger scale or to look to organizations like the United Nations for guidance, a feature that contrasts with many local efforts elsewhere in the world.

Third, public participation features prominently in community-level sustainability indicator efforts in the United States, which is not surprising given the character of U.S. politics. Indeed, it is unlikely that such efforts could obtain popular support without significant public participation. Most local advocates of sustainability realize that the implementation of sustainability requires action by the public, either in political forums (primarily as voters) or in the marketplace (primarily as consumers). Thus, they see the generation of interest in indicators as a way to get on the path to sustainable development. Of course, the same may be true elsewhere in the world.

Moving beyond the Vague

Although cynics may claim that sustainability is just the latest buzz word to include in reports and project proposals, a review of the many definitions in use shows that there is a growing convergence in the meaning of this term. Three concepts in particular are reflected in many of these definitions: that natural resources are finite and there are limits to the carrying capacity of the Earth's ecosystems; that economic, environmental, and social goals

must be pursued within these limits; and that there is a need for inter- and intragenerational equity.

Although there is growing consensus that development objectives have to respect the boundaries set by the biosphere, there is still a wide gap between developing and developed countries as to the relative priorities of economic and environmental goals. Developing countries still emphasize economic growth and increases in material possessions as ways to improve the quality of life. In developed countries, by contrast, quality of life is beginning to be seen less in terms of material possessions and more in terms of the quality of the time spent in various activities, the quality of personal relationships, and personal well-being.[26] Thus, while developing countries are understandably most concerned about living better, developed countries are beginning to think about living well within certain limits.

So far, the convergence on the meaning of sustainability is not being seen in the indicators used to measure progress toward it. In many cases, the indicators proposed are simply combined lists of traditional economic, environmental, and social indicators with the word sustainable added to the title. To be sure, combining different types of indicators in this way is a significant first step: It recognizes that all three areas are important and the discussions that attend it help give meaning to the somewhat abstract concept of sustainability. It is extremely important, however, that the development of indicators not stop there. Unconnected indicators encourage the same fragmented view of the world that has historically led to some of our most serious problems. Decision makers need indicators that show the links between social, environmental, and economic goals to better understand how to achieve economic growth that is in harmony with--rather than at the expense of--the natural systems within which we live. And there remains a need for criteria for evaluating indicators that can be understood by decision makers at all levels.

Questions also remain as to whether or not individual indicators can or should be aggregated. There are two issues here: how to represent the concept of sustainability meaningfully and accurately in a compact form, and how to connect different sustainability indicator sets to each other. Indices may be useful in resolving the first issue, although every index contains hidden assumptions and simplifications and so needs to be used judiciously. On the second issue, connecting indicators will not be a simple task because physical and social systems often act differently at different scales. For example, a long-term decline in the world price of petroleum would be good for the U.S. economy overall but bad for Texas and Louisiana. Similarly, a rise in sea level appears simply as faster beach erosion from a local perspective. Such difficulties, of course, complicate the job of national governments, which need to consolidate the large amounts of information available to them. (On the other hand, one-size-fits-all indicators may not suit governments at lower levels and organizations with a local, state, or regional focus.) Most importantly, before there is any attempt at aggregation, it should be clear why it is being done and what decisions will be informed by it.

Despite these problems, decision makers will often be forced to aggregate different sustainability indicators when comparing options. Similar problems attend processes that involve the public in decisionmaking. One tool that may prove useful in easing these difficulties is multicriteria analysis, which can use some or all of a community's sustainability indicators to evaluate a specific choice.[27] This technique can help a decision maker determine which indicators are most affected by the particular decision at hand and show how the different options compare in this regard. Many observers have called for such efforts, including the President's Council on Sustainable Development.[28] An approach of this type could help meet two difficult challenges: aggregating indicators

without either being misleading or ignoring processes with biogeophysical limits; and appropriately weighting those objectives that do compete.

One aspect of the development and use of sustainability indicators is unsurprising: They tend to reflect the education, experience, and concerns of the organizations that produce them. Thus, there are often sharp differences between indicators developed by physical scientists and those developed by social scientists, and one frequently hears complaints that the former ignore social issues while the latter do not have enough scientific input. Of course, no one group has the ultimate authority to define sustainability, and different individuals and organizations will continue to hold their own views on the subject. In some cases, it would be useful to recognize that sustainability cannot be a purely objective concept and will require collaboration on many levels. In other cases, however, greater reliance on technical expertise would improve efforts to measure and represent sustainability.

While sustainability indicators do not bring about change themselves, they are a valuable tool for understanding what change might be like. The idea of measuring the elusive concept of sustainability has clearly taken root, but many challenges and opportunities lie ahead. However, by moving us beyond vague--but important--discussions about sustainability in the abstract, indicators are already helping us not only to establish numerical goals and analyze trends but also to explore the full implications of this concept.

NOTES

1. For representative views, see J. Pezzy, Sustainable Development Concepts: An Economic Analysis (Washington, D.C.: World Bank, 1992): A. Heyes and C. Liston-Heyes, "Sustainable Resource Use: The Search for Meaning," Energy Policy 23, no. 1 (1995): 1; and W. McKibben, "Buzzless Buzzword," New York Times, 10 April 1996. A19.

2. The carrying capacity of an ecosystem (be it a particular biome or the entire planet) is the maximum number of individuals of a given species that the ecosystem can support indefinitely. It depends on two factors: the resources that are available and the quantity of resources that individuals of that species require for survival. Any population that exceeds its resource requirements will necessarily decline, and it may seriously impair the ecosystem itself in the process. For most species, carrying capacity is a fairly straightforward concept because the species' habitat is clearly delimited and its resource requirements are fixed. Humans are a more complex case because their requirements change dramatically over time due to technological advance (and can even decline on a per capita basis even though the standard of living is rising) and because they have the ability to effect vast changes to the natural ***environment*** throughout the planet.

3. See M. Sagoff, The Economy of the Earth (Cambridge, U.K.: Cambridge University Press, 1988); H. Daly and J. Cobb, For the Common Good (Boston, Mass.: Beacon Press, 1993); World Wildlife Fund, Sustainable Use of Natural Resources (Gland, Switzerland, 1993); and United Nations Development Programme, Human Development Report (New York: Cambridge University Press, 1994).

4. World Commission on ***Environment*** and Development, Our Common Future (Oxford, U.K.: Oxford University Press, 1987), 6-7.

5. World Conservation Union, Caring for the Earth: A Strategy for Survival (London: Mitchell Beazley, 1993), 211.

6. See G. Gallopin, "Indicators and Their Use: Information for Decision-making," in B. Moldan and S. Billharz, eds., Sustainability Indicutors (New York: John Wiley & Suns, 1997).

7. See L. Braat, "The Predictive Meaning of Sustainability Indicators," in O. Kuik and H. Verbruggen, eds., In Search of Indicators of Sustainable Development (Boston, Mass.: Kluwer Academic Publishers, 1992), 57.

8. V. Maclaren, Developing Indicators of Urban Sustainability: A Focus on the Canadian Experience (Toronto: International Committee on Urban and Regional Research Press, 1996).

9. Ibid.; M. Hart, Guide to Sustainable Community Indicators (Ipswich, Mass.: QLF/Atlantic Center for the ***Environment***, 1995): Tyler Norris Associates et al., The Community Indicators Handbook: Measuring Progress toward Healthy and Sustainable Communities (San Francisco. Calif.: Redefining Progress, 1997); and R Hardi and T Zdan, Assessing Sustainable Development: Principles in Practice (Winnipeg, Man.: International Institute of Sustainable Development, 1997).

10. These principles are available at http://iisdl. iisd.ca/measure/bellagiol.htm.

11. Moldan and Billharz, note 6 above, contains accounts of 10 national efforts and 1 multinational one. To facilitate these efforts, the United Nations Commission on Sustainable Development has prepared a handbook that provides detailed descriptions of some 130 indicators. Each description includes the indicator's place in the overall set, its significance, recommended methods for calculating it, and information on data needs and sources. See United Nations Commission on Sustainable Development. Indicators of Sustainable Development: Framework and Methodologies (New York, 1996).

12. President's Council on Sustainable Development, Sustainable America: A New Consensus for Prosperity, Opportunity, and a Healthy ***Environment*** for the Future (Washington, D.C.: U.S. Government Printing Office, 1996). The council identifies some sustainability indicators on pages 15-23.

13. For details, visit http://www.hq.nasa.gov/iwgsdi. html.

14. See http://www.fs.fed.us/intro/speech/roundtable. html.

15. See, for instance, http://www.epa.gov/region03/sdwork and http://www.epa.gov/ecocommunity/.

16. For free on-line training and a downloadable version, see http://www.subjectmatters.com/indicators/ HTMLSrc/IndicatorTrain.html.

17. W. Jung, "Sustainable Development in Industrial Countries: Environmental Indicators and Targets as Core Elements of National Action Plans--the German Case," Sustainable Development 3 (1998): I.

18. Ibid.: and D. Pearce, Blueprint 3: Measuring Sustainable Development (London: Earthscan, 1993).

19. FOE has worked with non-European nations as well, including China, Japan, Australia, Ghana, and Uruguay. See http://www.wx4all.nl/~foeint/suscamp. html.

20. M. Altieri and O. Masera, "Sustainable Rural Development in Latin America: Building from the Bottom Up," Ecological Economics 7, no. 1 (1993): 93; and Moldan and Billharz, note 6 above.

21. C. Azar et al., "Socio-ecological Indicators for Sustainability," Ecological Economics 18, no. 2 (1996): 89; D. Kezell. "Development of a Decision-Support System for a Regional Energy and Environmental Sustainability Model" (master's thesis, Arizona State University, 1991); and R. Ayres, "Statistical Measures of Unsustainability," Ecological Economics 16, no. 3 (1996): 239.

22. For details, visit http://www.scn.org/sustainable/ susthome.html.

23. See gopher://gopher.un.org/00/esc/cn17/1997-98/ patterns/mccpp5-9.txt.

24. King County Office of Budget and Strategic Planning, King County Benchmark Report (Seattle, Wash., 1996); and Pierce County Department of Community Services, Pierce County Quality of Life Benchmarks: Annual Report (Tacoma. Wash., 1998).

25. Department of Economic Development and Planning, Sustainability Indicators for Fife: Measuring the Quality of Life and the Quality of the ***Environment*** in Fife (Fife, Scotland, 1995).

26. Extensive empirical research and theoretical work on this issue has been assembled to explain this phenomenon, which is called postmaterialism. See R. Abramson and R. Inglehart, Value Change in Global Perspective (Ann Arbor, Mich.: University of Michigan Press, 1995).

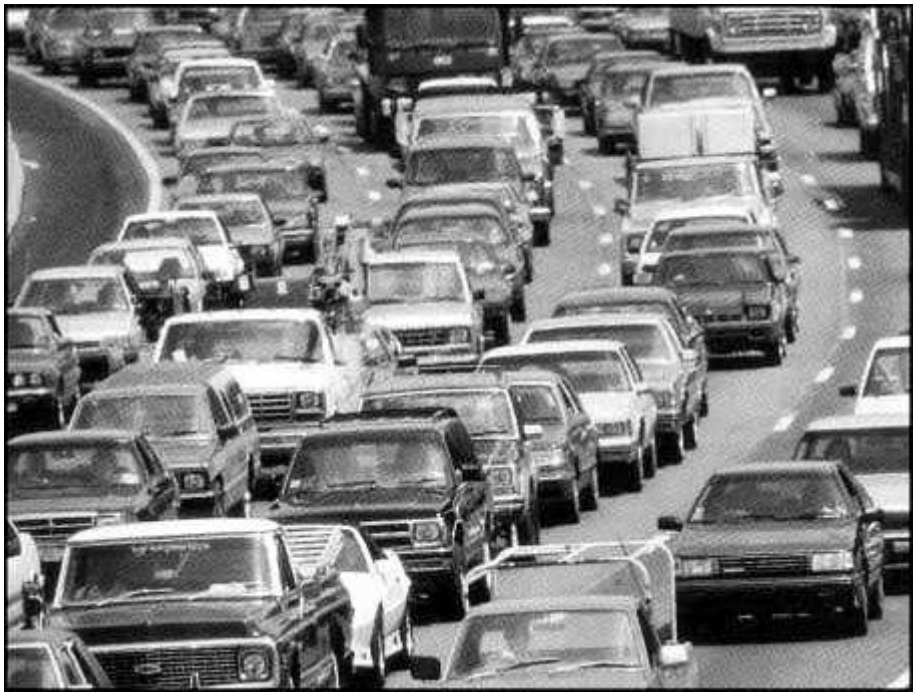
27. A. ***Farrell***, "Sustainability and the Design of Knowledge Tools," Technology & Society 15, no. 4 (1996): 11: and J. Herkert et al., "Technology Choice in a Sustainable Development Context," Technology & Society 15, no. 2 (1996): 12.

28. President's Council on Sustainable Development, note t 2 above.

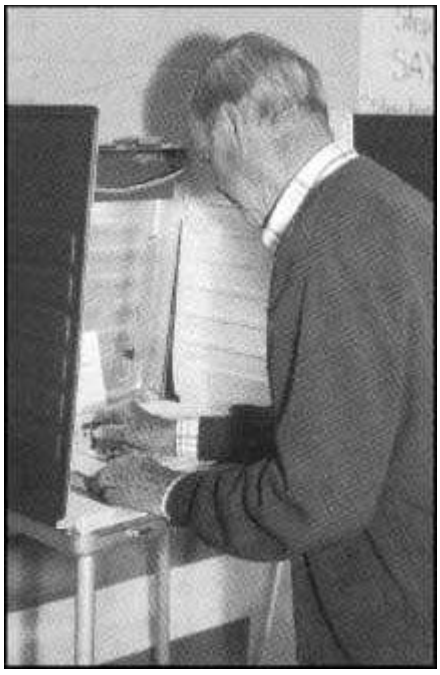
Population growth, which affects the quality of life on many levels, is one of the most significant factors in the whole question of sustainability.

Indicator sets often include factors related to agriculture, including cropland losses, irrigation. and chemical use.

Without significant public participation, efforts to develop indicators at the local level will not have adequate support.



Transportation is another major factor in the question of sustainability, with implications for energy use, pollution, and congestion.



Basic democracy is often a sustainability goal.

Sustainability decisions ultimately depend on the amount and quality of information available to the public and decision makers.

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Inset Article

FRAMEWORKS FOR SUSTAINABILITY INDICATOR SETS

Sustainability indicator sets are generally developed within a framework that not only organizes them but also shows whether or not they are balanced. that is. whether or not they reflect the full range of sustainability concerns. There are three common frameworks in use: the topic of interest. the goals of the developers. and the pressure-state-response framework.[1] A topic-based framework groups indicators by specific topic areas. such as the economy, the ***environment***, transportation, pollution. and so forth. With this framework. one can readily determine the degree of balance by looking at the number of indicators used for each topic, but it has the disadvantage of tending to use traditional indicators that sometimes conflict. For example. traditional measures of economic growth fail to reflect the increases in pollution that generally accompany growth. Thus. topic-based frameworks make it hard to see the linkages between areas and provide no impetus for the development of better indicator sets.

The goal-based framework organizes indicators into a matrix showing how each indicator relates to all the different sustainability goals of a particular community or other entity. As long as the goals adequately represent the desires of the community, this framework ensures that the indicator set reflects the full range of desires. It also shows the links between goals, as certain indicators can measure progress toward multiple goals. For example, "the number of acres of sustainably managed farmland" could measure progress toward the sustainable use of a natural resource (land) as well as that toward a healthy economy. The disadvantage to this framework is that if the goals are not representative. the resulting indicator set will not be representative either.

The pressure-state-response framework was developed by the Organisation for Economic Cooperation and Development as a way of analyzing environmental indicators. (The United Nations Commission on Sustainable Development has since modified this framework by substituting the concept of "driving forces" for "pressure" to include the social, economic. and institutional factors that affect sustainability.[2]) This framework focuses on those human activities (the pressures) that lead to particular environmental conditions (the states) and ultimately to remedial actions (the responses). Poor air quality, for example, is a state, one of the contributing pressures for which is automobile emissions; one possible response is to establish automobile emissions standards. This framework is very useful for describing the causes of problems and for understanding the linkages between the economy, the ***environment***, and society. One disadvantage is that it can be difficult to apply to social and economic indicators. For example, "the number of people driving cars" is a pressure with respect to air quality, a state with respect to transportation. and a response indicator with respect to land use patterns. Although such an indicator has the virtue of highlighting the links among several different aspects of sustainability, one must be clear how such an indicator is used in any specific case and whether an

increase or decrease is preferred.

1. V. Maclaren. Developing Indicators of Urban Sustainability: A Focus on the Canadian Experience (Toronto: International Committee on Urban and Regional Research Press, 1996).

2. United Nations Department of Economic and Social Affairs. Division of Sustainable Development, "Measuring Changes in Consumption and Production Patterns" (background paper for the Workshop on Indicators for Changing Consumption and Production Patterns, New York, 2-3 March 1998).

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SELECTED INDICATORS

United Nations Commission on Sustainable Development

Income inequality

Population growth rate

Difference between male and female school enrollment rates

Per capita consumption of fossil fuels for transportation

The ratio of the average house price to average income

Living space (floor area) per person

Environmentally adjusted net domestic product

Energy consumption

The intensity of materials use

Percentage of the population with adequate excreta disposal facilities

Share of renewable energy resources consumed

Annual withdrawals of ground and surface water

The ratio of debt service to export earnings

Amount of new funding for sustainable development

The maximum sustained yield for fisheries

Changes in land use

Percent of arable land that is irrigated

Energy use in agriculture

Percentage of forest area that is protected

Emissions of greenhouse gases

Waste recycling and reuse

Access to information

The representation of major groups on national councils for sustainable development

NOTE: The United Nations Commission on Sustainable Development has identified a total of 134 indicators of sustainability (see gopher://gopher.un.org/00/esc/cn17/1997-98/pattern/mccppS-9.txt).

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SUSTAINABILITY INDICES

An index is a single measure that combines many individual pieces of information by means of a precise mathematical formula. A familiar example is the Consumer Price Index, which is a weighted average of the prices for individual goods and services where the weights are the relative shares of those goods and services in consumer purchases overall. Sustainability indices, however, pose a problem that economic indices generally do not, namely, finding a common unit by which to measure all of the variables in which analysts are interested. There are two basic solutions to this problem: to use monetary equivalents or to use some common physical parameter.

Monetary Measures

Monetary measures of sustainability are essentially modifications of well-known economic indicators designed to measure growth. They represent an attempt by economists to incorporate the concept of sustainability into an existing theoretical framework so that they can bring familiar techniques and insights to bear on the issue. Another important rationale for this approach is that it gives decision makers environmental information in a form with which they are familiar and in which it can readily be compared with other types of information. Monetary indices are of two general types, those pertaining to "green national accounting" and those that attempt to measure general well-being.

Green national accounting entails modifying the System of National Accounts (SNA) to include environmental factors. The SNA framework was developed by the United Nations. it sets the standards for measuring gross domestic product (GDP) and other parameters needed to understand a nation's economy, such as the current account balance, wealth, and government income and expenditures. Such parameters, of course, are crucial in making many policy decisions, but they tend to exclude important environmental factors because those factors are not reflected in market activities.

Green national accounting does not replace the SNA system; rather, it attempts to bring environmental issues into the existing framework through satellite accounts.[1] These satellite accounts principally measure changes in natural resource balances and the damage caused by pollution. For example, when a forest is cleared to produce lumber, the value of the lumber would be recorded as part of GDP in the usual way, but a satellite account for forests would also show a decrease in the value of the forest itself. Analysis might then reveal that this decrease was related to the loss of other sorts of revenue (such as income from tourism), along with environmental degradation such as erosion and siltation in streams. However, green national accounting does not include reductions in ecosystem services that lie completely outside the market, such as the wildlife habitat that the forest provides. Furthermore, green national accounting does not address social issues even though such issues are central to many people's understanding of sustainability. Therefore, it is not surprising that broader indicators of well-being have emerged as well.

Perhaps the best known of these new indicators are the Index of Sustainable Economic Welfare (ISEW) and the related Genuine Progress Index (GPI), which come in the wake of a long history of efforts by economists to improve the measurement of welfare.[2] To calculate the values of these indices, one starts with a standard national accounting measure such as personal income or consumption and adjusts this for a variety of factors, including income inequality, defensive expenditures like cleaning up pollution, and environmental degradation. Calculations for the United States, Austria, the United Kingdom, and Scotland show that the ISEW is significantly lower than GDP and has not increased since about 1970.[3]

Nonmonetary Measures

Nonmonetary measures of sustainability are composite indicators that use a metric other than money, usually some sort of physical parameter such as the amount of nonrenewable energy a society uses. Nicholas Georgescu-Roegen first rigorously applied thermodynamic concepts (particularly entropy) to economic systems, and economist Kenneth Boulding extended these ideas with his notion of a "spaceship economy" in which the Earth is a spaceship that is closed materially but receives energy from the sun.[4] According to this conception, the Earth has a certain amount of stored energy in the form of fossil fuels, but once that stock is depleted it will be necessary to rely on solar inputs alone.[5] Energy-based sustainability indices reflect the critical limits view of sustainability because there is no effort to measure factors such as education or employment. Even so, it is not clear how factors like biodiversity can be meaningfully transformed into thermodynamic measurements.

A closely related and widely known measure is the "ecological footprint" developed by land-use planners William Rees and Mathias Wackernagel.[6] This indicator is based on the idea that one can assess sustainability in terms of the amount of land that is required to produce goods and services for (and absorb the pollution from) a person, city, country, or other entity. The focus of the ecological footprint is on consumption and the flow of materials and energy through human systems. Because of its simplicity, it may be a useful tool for promoting dialogue between various community groups interested in sustainability or as a means of education. However, this measure is limited in that it does not address the social or economic components of sustainability very well.

A third nonmonetary indicator is the Human Development Index (HDl) published by

the United Nations in its annual Human Development Report.[7] This indicator is constructed by calculating a normalized sum of life expectancy, adult literacy, education, and income.[8] One of the primary purposes of the HDl is to study how economic growth relates to other aspects of human development. Thus it reflects the competing-objectives view of sustainability even though it contains no environmental information. While some analysts find the HDl useful in fostering discussion of the appropriate forms of development, others point out thai there are strong correlations among the various components and thus that little is gained by having a more extensive (and subjective) measure.[9] One limitation of this indicator is that it does not address the ecological issues pertaining to sustainability or those of equity (except when comparing different areas). Furthermore. because the HDl is additive, it implies that its components are all directly comparable and substitutable for each other (e.g., more literacy can compensate for lower income).

1. See R. Repetto, "Earth in Balance Sheet: Incorporating Natural Resources in National income "National Accounts and ***Environment*** Resources,' ***Environment*** and Resource Economics 1, no. 1 (1991): 1; P. Bartelmus and J. von Tongren, "Integrated Environmental and Economic Accounting: Framework for an SNA Satellite System," review of Income and Wealth 2 (1991); and United Nations Department for Economic and Social Information and Policy Analysis, Integrated Environmental and Economic Accounting: Interim Version (New York: United Nations, 1993).

2. See H. Daly and J. Cobb, For the Common Good (Boston, Mass.: Beacon Press, 1993); C. Cobb et al., "If the GDP Is Up, Why Is America Down?," Atlantic Monthly, October 1995, 59; C. Cobb and J. Cobb, The Green National Product: A Proposed Index of Sustainable Economic Welfare (Lanham, Md.: University Press of America, 1994A); W. Nordhaus and J. Tobin, Is Growth Obsolete? (New York: Columbia University Press, 1972); and I. Moffat, "On Measuring Sustainable Development Indicators," International Journal of Sustainable Development and World Ecology 1, no. 2 (1991): 97.

3. T. Jackson and N. Marks, Measuring Sustainable Economic Welfare: A pilot Index 1950-1990 (Stockhom: Stockholm ***Environment*** Institute, 1994); I. Moffat and M. Wilson, "An Index of Sustainable Economic Welfare for Scotland, 1980-1991," International Journal of Sustainable Development and World Ecology 1, no. 4 (1991): 264; and E. Stockhammer et al., "The Index of Sustainable Economic Welfare (ISEW) as an Alternative to GDP in Measuring Economic Welfare: The Results of the Austrian (Revised) ISEW Calculation 1955-1992," Ecological Economics 21, no. 1 (1992): 10.

4. N. Georgescu-Roegen, The Entropy Law and the Economic Process (Cambridge, Mass.: Harvard University Press, 1971), 145; and K. Boulding, The Economics of the Coming Spaceship Earth (Baltimore, Md." John Hopkins University Press, 1966), 3-14.

5. H. Odum, "Energy in Ecosystems," in N. Polunin, ed., Environmental Monographs and Symposia (New York: John Wiley and Sons, 1986): C. Cleveland, "Natural Resource Scarcity and Economic Growth Revisited: Economic and Biophysical Perspective," in R. Costanza, ed., Ecological Economics (New York: Columbia University Press, 1991), 289; J. Gever et al., Beyond Oil: The Threat to Food and Fuel in the Coming Decades (Cambridge, Mass.: Harper & Row, 1986); and R. Ayres and K. Martinas, "Waste Potential Energy: The Ultimate Ecotoxic," Economic Applications 43, no. 2 (1995).

6. M. Wackernagel and W. Rees, Our Ecological Footprint: Reducing Human Impact on the Earth (Gabriola Island, B.C.: New Society Publishers, 1996).

7. United Nations Development Programme, Human Development Report 1990 (New York: Cambridge University Press, 1994).

8. The four indicators are normalized before they are added, that is, each is converted to a value between 0 and 1 using a fixed scale. The scale for life expectancy runs from 25 years (which assumes the value 0) to 85 years (which assumes the value 1). Similarly, income is measured as per capita GDP (on a purchasing power parity basis) on a scale from $200 to $40,000; adult literacy is the percentage of literate adults divided by 100; and education is measured as the average number of years of school completed from 0 to 15. All of these adjustments, however, reflect significant normative judgements that go to the heart of what sustainability means. As a result, they deserve much more scrutiny by both researchers and the public.

9. V. Rao. "Human Development Report 1990: Review and Assessment," World Development 19, no. 10 (1991): 1,454; and M. McGillivray, "The Human Development Index; Yet Another Redundant Composite Development Indicator?," World Development 19, no. 10 (1991): 1,461.

Inset Article

THE SUSTAINABILITY INDICATOR SET FOR FIFE, SCOTLAND

Basic Needs

Number of households registered as homeless

Average energy efficiency rating of homes

Number of people unemployed for more than one year

Poverty rate (number of claims for financial support)

Transportation alternatives (kilometers of bicycle routes)

Community

Average life expectancies at birth for men and women

Number of deaths in the first year of life per 1.000 live births

Reported cases of crimes of violence. burglary, and indecent assault

Number of placements in Fife Regional Council Nurseries

Number of accidents involving injury to pedestrians and cyclists

Quality of the *environment*

Number of square kilometers of land lost to development

Number of submerged plant species m selected lochs

Water quality (the concentration of nitrates in the water in boreholes)

Number of complaints to local authorities about noise

Air quality (the ratio of sulfur dioxide and smoke to the limits set by the European Community)

Use of resources

Number of people employed in agriculture

Tons of fish landed at Fife ports

Household waste per person

Percentage of population with sewage discharged to the sea untreated or partially treated

Total energy consumption

SOURCE: Department of Economic Development and Planning, Sustainability, Indicators for Fife: Measuring the Quality of Life and the Quality of the ***Environment*** in Fife (Fife, Scotland, 1995).

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