MuseLetter #178 / February 2007

Five Axioms of Sustainability

My aim in this essay is to explore the history of the terms *sustainable* and *sustainability*, and their various published definitions, and then to offer a set of five axioms (based on a review of the literature) to help clarify the characteristics of a durable society.

The essence of the term *sustainable* is simple enough: "that which can be maintained over time." By implication, this means that any society, or any aspect of a society, that is unsustainable cannot be maintained for long and will cease to function at some point.

It is probably safe to assume that no society can be maintained forever: astronomers assure us that in several billion years the Sun will have heated to the point that the oceans will have boiled away and life on our planet will have come to an end. Thus *sustainability* is a relative term. It seems reasonable to take as a temporal frame of reference the durations of prior civilizations, which ranged from several hundreds to several thousands of years. A sustainable society, then, would be one capable of maintaining itself for many centuries into the future.

However, the word *sustainable* has become widely used in recent years to refer, in a general and vague way, merely to practices that are reputed to be more environmentally sound than others. Often the word is used so carelessly as to lead some environmentalists to advise abandoning its use.[1] Nevertheless, I believe that the concept of sustainability is essential to the understanding and solution of our species' ecological dilemma, and that the word is capable of rehabilitation, if only we are willing to expend a little effort in arriving at a clear definition.

History and Background

The essential concept of sustainability was embodied in the worldviews and traditions of many indigenous peoples; for example, it was a precept of the *Gayanashagowa*, or Great Law of Peace (the constitution of the Haudenosaunee or Six Nations of the Iroquois Confederacy) that chiefs consider the impact of their decisions on the seventh generation to come.

The first known European use of *sustainability* (German: *Nachhaltigkeit*) occurred in 1712 in the book *Sylvicultura Oeconomica* by German forester and scientist Hannss Carl von Carlowitz. Later, French and English foresters adopted the practice of planting trees as a path to "sustained yield forestry."

The term gained widespread usage after 1987, when the Brundtland Report of the World Commission of Environment and Development defined *sustainable development* as development that "meets the needs of the present generation without compromising the ability of future generations to meet their own needs."[2] This definition of sustainability has proven extremely influential, and is still widely used; nevertheless it has been criticized for its failure to explicitly note the unsustainability of the use of non-renewable resources, and for its general disregard of the problem of population growth.[3]

Also in the 1980s, Swedish oncologist Dr. Karl-Henrik Robèrt brought together leading Swedish scientists to develop a consensus on requirements for a sustainable society. In 1989 he formulated this consensus in four conditions for sustainability, which in turn became the basis for an organization, The Natural Step.[4] Subsequently, 60 major Swedish corporations and 56 municipalities, as well as many businesses in other nations, pledged to abide by Natural Step conditions. The four conditions are as follows:

1. In order for a society to be sustainable, nature's functions and diversity are not systematically subject to increasing concentrations of substances extracted from the earth's crust.
2. In order for a society to be sustainable, nature's functions and diversity are not systematically subject to increasing concentrations of substances produced by society.
3. In order for a society to be sustainable, nature's functions and diversity are not systematically impoverished by physical displacement, over-harvesting, or other forms of ecosystem manipulation.
4. In a sustainable society, people are not subject to conditions that systematically undermine their capacity to meet their needs.

Seeing the need for an accounting or indicator scheme by which to measure sustainability, Canadian ecologist William Rees in 1992 introduced the concept of the Ecological Footprint, defined as the amount of land and water area a human population would hypothetically need in order to provide the resources required to support itself and to absorb its wastes, given prevailing technology.[5] Implicit in the scheme is the recognition that, for humanity to achieve sustainability, the total world population's footprint must be less than the total land/water area of the Earth (that footprint is currently calculated by the Footprint Network as being about 23 percent larger than what the planet can regenerate, indicating that humankind is to this extent operating in an unsustainable manner).

In a paper published in 1994 (revised 1998), professor of physics Albert A. Bartlett offered 17 Laws of Sustainability, with which he sought to clarify the meaning of *sustainability* in terms of population and resource consumption.[6] Bartlett's criticisms of the careless use of the term, and his rigorous demonstration of the implications of continued growth, were important influences on the present author's efforts to define what is genuinely sustainable.

A truly comprehensive historical survey of the usage of the terms *sustainable* and *sustainability* is not feasible. A search of Amazon.com for *sustainability* (January 17, 2007) yielded nearly 25,000 hits—presumably indicating several thousand distinct titles containing the word. *Sustainable* yielded 62,000 hits, including books on sustainable leadership, communities, energy, design, construction, business, development, urban planning, tourism, and so on. A search of journal articles on Google Scholar turned up 538,000 hits, indicating thousands of scholarly articles or references with the word *sustainability* in their titles. However, my own admittedly less-than-exhaustive acquaintance with the literature (informed, among other sources, by two books that offer an overview of the history of the concept of sustainability)[7] suggests that much, if not most of this immense body of publications repeats, or is based on, the definitions and conditions described above.

Five Axioms

As a contribution to this ongoing refinement of the concept, I have formulated five axioms (self-evident truths) of sustainability. I have not introduced any fundamentally new notions in any of the axioms; my goal is simply to distill ideas that have been proposed and explored by others, and to put them into a form that is both more concise and easier to understand.

In formulating these axioms I endeavored to take into account previous definitions of *sustainability*, and also the most cogent criticisms of those definitions. My criteria were as follows:

- To qualify as an axiom, a statement must be capable of being tested using the methodology of science;
- Collectively, a set of axioms intended to define *sustainability* must be minimal (with no redundancies);
- At the same time, the axioms must be sufficient, leaving no glaring loopholes; and
- The axioms should be worded in terms the layperson can understand.

Here are the axioms, each followed by a brief discussion:

1. (Tainter's Axiom): Any society that continues to use critical resources unsustainably will collapse.

Exception: A society can avoid collapse by finding replacement resources.

Limit to the exception: In a finite world, the number of possible replacements is also finite.

Discussion: I have named this axiom for Joseph Tainter, author of the classic study, *The Collapse of Complex Societies,* which demonstrates that collapse is a frequent if not universal fate of complex societies, and argues that collapse is directly related to declining returns on efforts to support growing levels of societal complexity with energy harvested from the environment. Jared Diamond's book *Collapse: How Societies Choose to Fail or Succeed* similarly makes the argument that collapse is the common destiny of societies that ignore resource constraints.[9]

This axiom defines sustainability by the consequences of its absence, i.e., collapse. Tainter defines *collapse* as a reduction in social complexity—i.e., a contraction of society in terms of its population size, the sophistication of its technologies, the consumption rates of its people, and the diversity of its specialized social roles. Often, historically, collapse has meant a precipitous decline in population brought about by social chaos, warfare, disease, or famine. However, collapse can also occur more gradually over a period of many decades or even several centuries. There is also the theoretical possibility that a society could choose to collapse (i.e., reduce its complexity) in a controlled as well as gradual manner.

While it could be argued that a society can choose to change rather than collapse, the only choices that would substantively affect the outcome would be either to cease using critical resources unsustainably or to find alternative resources.

A society that uses resources sustainably may collapse for other reasons, some beyond the society's control (as a result of an overwhelming natural disaster, or of conquest by another, more militarily formidable and aggressive society, to name just two of many possibilities), so it cannot be said that a sustainable society is immune to collapse unless many more conditions for sustainability are specified. This first axiom focuses on resource consumption because that is a decisive, quantifiable, and, in principle, controllable determinant of a society's long-term survival.

The question of what constitutes sustainable or unsustainable use of resources is addressed in axioms 3 and 4.

Critical resources are ones essential to the maintenance of life and basic social functions —including (but not necessarily limited to) water and the resources necessary to produce food and usable energy.

The *Exception* and *Limit to the Exception* address the common argument of free-market economists that resources are infinitely substitutable, and that therefore modern market-driven societies need never face a depletion-led collapse even if their consumption rates continue to escalate.[8] In some instances, substitutes for resources become readily available and are even superior, as was the case in the mid-19th century when kerosene from petroleum was substituted for whale oil as a fuel for lamps. In other cases, substitutes are inferior (as is the case with tar sands as a substitute for conventional petroleum, given that tar sands are less energy-dense, require more energy input for processing, and produce more carbon emissions). As time goes on, societies will tend first to exhaust substitutes that are superior and easy to get at, then those that are equivalent, and increasingly will have to rely on ever more inferior substitutes to replace depleting resources—unless rates of consumption are held in check (see Axioms 2–4).

2. (Bartlett's Axiom): Population growth and/or growth in the rates of consumption of resources cannot be sustained.

Discussion: I have named this axiom for Albert A. Bartlett because it is his First Law of Sustainability, reproduced verbatim (I found it impossible to improve upon).[10]

The world has seen the human population grow for many decades and therefore this growth has obviously been sustained up to the present. How can we be sure that it cannot be sustained into the indefinite future? Simple arithmetic can be used to show that even small rates of growth, if continued, add up to absurdly large—and plainly unsupportable—population sizes and rates of consumption. For example: a simple one percent rate of growth in the present human population (less than the actual current rate) would result in a doubling of population each 70 years. Thus in 2075, the Earth would be home to 13 billion humans; in 2145, 26 billion; and so on. By the year 3050, there would be one human per square meter of Earth's land surface (including mountains and deserts).

3. To be sustainable, the use of ***renewable*** resources must proceed at a rate that is less than or equal to the rate of natural replenishment.

Discussion: Renewable resources are exhaustible. Forests can be over-cut, resulting in barren landscapes and shortages of wood (as occurred in many parts of Europe in past centuries), and fish can be over-harvested, resulting in the extinction or near-extinction of many species (as is occurring today globally).

This axiom has been stated (in somewhat differing ways) by many economists and ecologists, and is the basis for "sustained yield forestry" (see above) and "maximum sustainable yield" fishery management. Efforts to refine this essential principle of sustainability are ongoing.[11]

The term "rate of natural replenishment" requires some discussion. The first clue that harvesting is proceeding at a rate greater than that of natural replenishment is the decline of the resource base. However, a resource may be declining for reasons other than over-harvesting; for example, a forest that is not being logged may be decimated by disease. Nevertheless, if the resource is declining, pursuit of the goal of sustainability requires that the rate of harvest be reduced, regardless of the cause of the resource decline. Sometimes harvests must drop dramatically, at a rate far greater than the rate of resource decline, so that the resource has time to recover. This has been the case with regard to commercial wild whale and fish species that have been over-harvested to the point of near-exhaustion, and have required complete harvest moratoria in order to re-establish themselves—though in cases where the remaining breeding population is too small even this is not enough and the species cannot recover.

Axiom 3 is implied in the Natural Step's third condition.

4. To be sustainable, the use of *non-renewable* resources must proceed at a rate that is declining, and the *rate of decline* must be greater than or equal to the *rate of depletion*.

The *rate of depletion* is defined as the amount being extracted and used during a specified time interval (usually a year) as a percentage of the amount left to extract.

Discussion: No continuous rate of use of any non-renewable resource is sustainable. However, if the rate of use is declining at a rate greater than or equal to the rate of depletion, this can be said to be a sustainable situation in that society's dependence on the resource will be reduced to insignificance before the resource is exhausted.

This principle was first stated, in a more generalized and more mathematically rigorous form, by Albert A. Bartlett in his 1986 paper, "Sustained Availability: A Management Program for Non-Renewable Resources."[12] The article's abstract notes:

> If the rate of extraction declines at a fixed fraction per unit time, the rate of extraction will approach zero, but the integrated total of the extracted resource between t=0 and t=infinity will remain finite. If we choose a rate of decline of the rate of extraction of the resource such that the integrated total of all future extraction equals the present size of the remaining resource then we have a program that will allow the resource to be available in declining amounts for use forever.

Annually reducing the rate of extraction of a given non-renewable resource by its yearly rate of depletion effectively accomplishes the same thing, but requires only simple arithmetic and layperson's terms for its explanation.

Estimates of the "amount left to extract," mentioned in the axiom, are disputable for all non-renewable resources. Unrealistically robust estimates would tend to skew the depletion rate in a downward direction, undermining any effort to attain sustainability via a resource depletion protocol. It may be realistic to assume that people in the future will find ways to extract non-renewable resources more thoroughly, with amounts that would otherwise be left in the ground becoming economically recoverable as a result of higher commodity prices and improvements in extraction technology. Also, exploration techniques are likely to improve, leading to further discoveries of the resource. Thus realistic estimates of ultimately recoverable quantities should be greater than currently known amounts extractable with current technology at current prices. However, it is unrealistic to assume that people in the future will ever be able to economically extract all of a given resource, or that limits of declining marginal returns in the extraction process will no longer apply. Moreover, if discovery rates are currently declining, it is probably unrealistic to assume that discovery rates will increase substantially in the future. Thus for any non-renewable resource prudence dictates adhering to conservative estimates of the "amount left to extract."

Axiom 4 encapsulates Bartlett's 7th and 8th Laws of Sustainability. It is also the basis for the Oil Depletion Protocol, first suggested by petroleum geologist Colin J. Campbell in 1996 and the subject of a recent book by the present author.[13] The aim of the Oil Depletion Protocol is to reduce global consumption of petroleum in order to avert the crises likely to ensue as a result of declining supply—including economic collapse and resource wars. Under the terms of the Oil Depletion Protocol, oil-importing countries would reduce their imports by the world oil depletion rate (calculated by Campbell at 2.5 percent per year); producers would reduce their domestic production by their national depletion rates.

5. Sustainability requires that substances introduced into the environment from human activities be minimized and rendered harmless to biosphere functions.

In cases where pollution from the extraction and consumption of non-renewable resources that has proceeded at expanding rates for some time threatens the viability of ecosystems, reduction in the rates of extraction and consumption of those resources may need to occur at a rate greater than the rate of depletion.

Discussion: If axioms 2 through 4 are followed, pollution should be minimized as a result. Nevertheless, these conditions are not sufficient in all cases to avert potential collapse-inducing impacts.

It is possible for a society to generate serious pollution from the unwise use of renewable resources (the use of tanning agents on hides damaged streams for centuries or millennia), and such impacts are to be avoided. Likewise, especially where large numbers of humans are concentrated, their biological wastes may pose severe environmental problems; such wastes must be properly composted.

The most serious forms of pollution in the modern world arise from the extraction, processing, and consumption of non-renewable resources. If (as outlined in Axiom 4) the consumption of non-renewable resources declines, pollution should also decline. Thus, in theory, if a society is following the terms of Axiom 4, these pollution problems are less likely to arise in the future.

However, in the current instance, where the extraction and consumption of non-renewable resources have been growing for some time and have resulted in levels of pollution that threaten basic biosphere functions, heroic measures are called for. This is of course the situation with regard to atmospheric concentrations of greenhouse gases, especially in relation to the burning of the non-renewable resource coal; it is also the case with regard to hormone-mimicking petrochemical pollution that inhibits reproduction in many vertebrate species. In the first instance: merely to reduce coal consumption by the global coal depletion rate would not suffice to avert a climatic catastrophe. The coal depletion rate is small, climate impacts from coal combustion emissions are building quickly, and annual reductions in those emissions must occur at high rates if ecosystem-threatening consequences are to be avoided. Similarly, in the case of petrochemical pollution, merely to reduce the dispersion of plastics and other petrochemicals into the environment by the annual rate of depletion of oil and natural gas would not suffice to avert environmental harms on a scale potentially leading to the collapse of ecosystems and human societies.

In the case that reduction in emissions or other pollutants can be obtained without a reduction in consumption of non-renewable resources, for example by using technological means to capture polluting substances and sequester them harmlessly, or by curtailing the production of certain industrial chemicals, then a reduction in consumption of such resources need only occur at the depletion rate in order to achieve sustainability. However, society should be extremely skeptical and careful regarding claims for untested technologies' abilities to safely sequester polluting substances for very long periods of time.

This axiom builds upon Natural Step condition 2.

Evaluation

These axioms are of course open to further refinement. I have attempted to anticipate criticisms likely to be leveled at them, which will probably be of the sort that says these axioms are not sufficient to define the concept of sustainability. The most obvious of these is worth mentioning and discussing here: *Why is there no axiom relating to social equity* (similar to the Natural Step's fourth condition)?

The purpose of the axioms set forth here is not to describe conditions that would lead to a good or just society, merely to a society able to be maintained over time. It is not clear that perfect economic equality or a perfectly egalitarian system of decision-making is necessary to avert societal collapse. Certainly, extreme inequality seems to make societies vulnerable to internal social and political upheaval. On the other hand, it could be argued that a society's adherence to the five axioms as stated will tend to lead to relatively greater levels of economic and political equality, thus obviating the need for a separate axiom in this regard. In anthropological literature, modest rates of resource consumption and low population sizes relative to the available resource base are often correlated with the use of egalitarian decision-making processes and with economic equity—though the correlation is skewed by other variables, such as means of sustenance (hunting-and-gathering societies tend to be highly equitable and egalitarian, while herding societies tend to be less so). If such correlations continue to hold, the reversion to lower rates of consumption of resources should lead to a more rather than less egalitarian society.[14]

Will local, national, and international leaders ever shape public policy according to these five axioms? Clearly, policies that would require an end to population growth—and perhaps even a population decline—as well as a reduction in the consumption of resources would not be popular, unless the general populace could be persuaded of the necessity of making its activities sustainable. However, if leaders do not begin to abide by these axioms, society as a whole, or some aspects of it, will assuredly collapse. Perhaps this is sufficient incentive to overcome the psychological and political resistance that would otherwise frustrate efforts toward true sustainability.

Notes

1. Eric Freyfogle, *Why Conservation Is Failing and How It Can Regain Ground* (Yale University Press, 2006)
2. World Commission of Environment and Development, "Our Common Future" (1987), www.are.admin.ch/are/en/nachhaltig/international_uno/unterseite02330/
3. Albert A. Bartlett, "Reflections on Sustainability, Population Growth, and the Evnironment—Revisted." *Renewable Resources Journal,* Vol. 15, No. 4, Winter 1997-1998, 6-23. www.hubbertpeak.com/bartlett/reflections.htm
4. www.naturalstep.org
5. William E. Rees and Mathis Wackernagel, *Our Ecological Footprint* (New Society, 1995). www.footprintnetwork.org
6. Bartlett 1998, op. cit.
7. Simon Dresner, *Principles of Sustainability* (Earthscan, 2002); Andres Edwards, *The Sustainability Revolution: Portrait of a Paradigm Shift* (New Society, 2005)
8. Julian Simon, "The State of Humanity: Steadily Improving." *Cato Policy Report,* Vol. 17, No. 5, 131.
9. Jared Diamond, *Collapse: How Societies Choose to Fail or Succeed* (Viking, 2005); Joseph Tainter, *The Collapse of Complex Societies* (Cambridge University Press, 1988)
10. Bartlett 1998, op. cit.
11. E.g., Simone Valente, "Sustainable Development, Renewable Resources and Technological Progress" in *Environmental and Resource Economics* Vol. 30, No. 1, January 2005, 115-125.
12. Albert A. Bartlett, "Sustained Availability: A Management Program for Nonrenewable Resources." *American Journal of Physics,* Vol. 54, May 1986, 398-402
13. Richard Heinberg, *The Oil Depletion Protocol: A Plan to Avert Oil Wars, Terrorism and Economic Collapse* (New Society, 2006); www.oildepletionprotocol.org
14. See, for example, Marshall Sahlins, *Stone Age Economics* (Aldine, 1972); Gerhard Lenski, *Power and Privilege* (University of North Carolina Press, 1977); and Ivan Illich, *Energy and Equity* (Calder and Boyars, 1974).