Design Principles for Sustainability

In any attempt to provide specific guidelines for the development of sustainable man-made settings, the essence of sustainability must be clearly defined. The following is an attempt to do this by enunciating certain principles, each of which encompasses one essential ingredient, the violation of which would be sufficient by itself to cause systemic decay. These principles should be the basis for evaluating possible design "solution concepts" in a given location. There are a standard to be achieved by any entity or process aspiring to secure tenure in the biosphere.

These principles of sustainability are:

1. *The Principle of Minimal Heat Drainage:* which requires the reduction of energy and material flow-through: the reduction entropy.
2. *The Principle of Simple Re-Production*: which requires the affiliation with systems capable of replenishing initial stocks.
3. *The Principle of Graceful Failure*: which requires properties of resilience and adaptability as effective resistance to sudden, total, and catastrophic failure.
4. *The Principle of Rational Transparency*: which requires the diffusion of control and responsibility, and maximum opportunity for personal creativity. It advocates direct rather than vicarious experiences of life.
5. *The Principle of Common Heritage*: which concerns issues of fairness, equity, communication, and cultural enrichment.
6. *The Principle of Natural Order*: which requires a tangible aesthetic quality.
7. *The Principle of Sacred Situation*: which requires a harmony with geomantic forces.

Introduction

Some basic human needs are those for energy, food, and water. In serving these needs, the pattern of a high-energy society has been to increase the scale of operation; to centralize services; and to eliminate human labor in favor of more powerful converters. These practices have brought benefits of greater disease control and increased convenience of living, but hey are also proving to be particularly damaging to the natural resource base and the human psyche.

The human social and environmentally debilitating effects of a high-energy society have been argued extensively in recent times. The U.N. conference in Stockholm in 1972 was a major forum of world concern. Concurrent expressions from such as Barry Commoner and Lester Brown in the U.S. and Edward Goldsmith et al in Britain in the early 1970's advanced the view that, in the words of the latter, "...the principal defect of the industrial way of life with its ethos of expansion is that it is not sustainable". More recently Eric Eckholm, reviewing the state of the global environment 10 years after the Stockholm conference, finds that while "...public understanding of environmental imperatives has increased over the last decade, ... many of the social, economic, and technical forces that underlie environmental difficulties have scarcely been checked". Most recently the September 1989 issue of Scientific American devoted itself entirely to the subject of "Managing Planet Earth" revealing that ever more problems had surfaced. With this background of chronic despoilation we are prompted to ask:

- What is the nature of a sustainable society?
- What essential characteristics must it possess?
- How must it differ from present society?

What follows is an attempt to define the essential attributes of sustainable settlement in terms of seven principles.

Principle of minimal heat drainage

In any real process involving the accomplishment of work, useful potential energy becomes lost. It is the inescapable condition explained by the Second Law of Thermodynamics known as increasing entropy.

Entropy describes the fate of energy. It is the process of transformation of available, "free" energy to unavailable, "bound" energy. Energy is not lost upon completion of work. It is, however, degraded to a lower order of usefulness, and ultimately to heat at the ambient temperature of the surrounding. Jeremy Rifkin provides a full-blown view of entropy as the irreversible progress toward oblivion, "...the creation of islands of order at the expense of seas of disorder". Within our current view of the physical universe, and without being an alarmist, it is a fact of life. It is, as Howard Odum[1] explains, "...the energy tax necessary for the operation". It is the heat drainage without which the process simply will not work.

Human activity is increasing entropy at an exponential rate. Expanding technology, ever deploying its energy converters at the behest of a market economy, hastens the dissipation of available energy. Corrections to compensate for the "external costs" of deployments inevitably speed up energy transformations, thereby further contributing to the entropy process. This first principle of sustainability requires the minimization of this loss of available energy. It can otherwise be expressed as the reduction in energy flow-through, or the reduction of entropy - or heat drainage.

There are two means by which heat drainage must be reduced if a sustainable human condition is to be achieved. The first is by reducing the actual amount of energy (especially from non-renewable stocks) converted. This is a question of need and is linked to prevailing social value systems.

The second concerns thermodynamic efficiency and involves matching the quality (its characteristic temperature) of an energy source with its desired end use. For example, heating a

[1] Odum [1971] “Environment, Power & Society” Wiley, p. 29.

house to around 70 F can be perfectly well accomplished by a heat source only slightly above that temperature -100 to 140 F . It does not need electricity, which is a high quality source capable of performing additional work at higher temperatures while being degraded to the point where space heating is appropriate end use. If such a mis-match occurs, even when the end use is considered socially useful, efficiency has been reduced and waste incurred because of the lost opportunity of work at higher temperatures. Matching the quality of an energy source to its end use is a designer's task, and is expressed succinctly. First, design each process to use energy of the lowest quality that is economically feasible, and second, provide the energy at a temperature just above that quality.

Therefore, as an over-arching principle of designing for sustainability, we must strive to reduce the slide toward entropy - to minimize heat drainage - by rising to both the human and the technical challenges[2].

The principle of simple reproduction

Fritz Schumacher said: "from an economic point of view, the central concept of wisdom is permanence. ... Nothing makes economic sense unless its continuance for a long time can be projected without running into absurdities[3]". To be viable, a system must be capable of reproducing itself.

Our present economic system is characterized by a straight line and by the notion of consumption. We act as though we were encamped between a munificent fountain and a bottomless pit. Cost is registered as a narrow band on the spectrum of consequences. Production is maintained by significant inputs of non-renewable capital stocks of stored up sunshine, which is expended in processing a continuous stream of raw resource material, and in pushing further away an ever-mounting pile of waste. It promises everything but permanence.

This second principle of sustainability eschews such systems. It rather requires the affiliation with systems capable of replenishing initial stocks, and which are characterized by circles or cycles, wherein the wastes of one process are seen as the raw materials of another process around the cycle. In this way the concept of a "waste" is replaced by the concept of a "nutrient". Howard Odum reflects this requirement in his insistence on feedback loops. He writes: "A reasonable plan of management [design] of a system of man and nature requires that all flows be evaluated and paid for with return services..."[4]. Pliny Fisk describes such productive feedback (or "feed-

---

[2] Another view of this condition is that proposed by Cook (1971). It is that the ultimate limitation on growth may not be the scarcity of concentrated ("free") energy or resources, which may be viewed as yielding in time to the "technical fix". It is rather the capacity of the planet to absorb the waste heat: the increasing entropy. In an article describing the flow of energy through an industrial society, Cook concludes: "In the long run the limiting factor in high levels of energy consumption will be the disposal of waste heat."

[3] E.F. Schumacher [1973] "Small is Beautiful: ...", Blond & Briggs.

[4] H. Odum, op. cit. p. 46

forward") as "metabolic units of production" (His work in Texas and Central America stand as excellent examples of this principle of simple reduction in action[5].) In all cases reproduction should be achieved as simply and directly as possible, or we stand in contravention of the first principle stated above. Soil conservation, for example, should be effected by sensible agricultural pratices rather than by running 5 million truckloads of eroded soil each year from the Gulf of Mexico back to Minnesota. The management of unintended by-products should be by reclamation of their essential constituents at the point of production.

Kenneth Boulding expresses this central concern, declaring in his paper espousing a steady-state "spaceship" economy that "...what we are primarily concerned with is stock maintenance.[6]" This is the essential concern of the principle of simple reproduction. It requires the valuing of our natural resources as fixed assets and organizing to prevent their dissipation. It for example requires designing products with their long life and the eventual reclamation of their constituents upheld as important initial design parameters.

More specifically it requires:
1) The internalization (the integration/absorption) of "external" or hidden costs;
2) The cycling of resources;
3) The dependence upon renewable energy and resources;

This second principle of sustainability is in essence against killing geese that lay golden eggs.

The principle of graceful failure

This principle prescribes that systems should not fail completely, suddenly, and catastrophically; but rather should exhibit sufficient resilience and adaptability to fail "gracefully". It could equally well be termed the principle of maximum diversity or "requisite variety"[7] for diversity contributes to so many of the conditions that enable a graceful, controlled failure or adaptation.

Resilient qualities flow from: redundancy, relative incoherence, cyclicality, and diversity all of which in essence are "negentropy[8]" - negative (or reduced) entropy. It is the peculiar quality of life that it is able to store sufficient of the incident, essentially negative entropy of solar radiation to sustain itself in the face of the natural thermo-dynamic decay of an otherwise closed system. This negative entropy is stored as high quality energy in the form of the vegetable biomass. It is also stored as information in the form of genetic codes amounting to the peculiarities of each life form and the variety of their functional capacity.

---

[5] See various pubs. of the Center for Maximum Potential Building Systems, Austin, TX.
[6] K. Boulding [1966] "The Economics of the Coming Spaceship Earth"
[7] This is a term used by W.K. Ashby in "Introduction to Cybernetics" – quoted by Coates [1981] "Resettling America", Brick House, p. 536. It requires that the scale of authority be reduced as the complexity of action increases.
[8] The word syntropy has also been applied to this phenomenon.

Redundancy ensures that the consequences of failure of one component are absorbed by others equally capable of discharging the given function therefore allowing such failure to be absorbed by the perseverance of other inter-acting, inter-connected parts. However this interdependence must not proceed to excess for it would be clearly disruptive if a change in one systemic component were to provoke an immediate and proportional change in all other components.

Therefore a stable system should maintain a balance between connectedness or redundancy on the one hand, and disconnectedness or "incoherence" on the other. Biological systems exhibit this balance, and from them we can observe that the amount of incoherence must be a function of scale. The larger or higher the level of the system, the greater the incoherence required for stability. The achievement of this balance is fundamental to the characteristic of natural systems noted by Edward Goldsmith writing in "The Ecologist" - "that as natural systems become more complex, so do they become more stable".
(Sub-conclusion about biology as a guide - stability as the bulwark against catastrophic failure)

Pursuing an interest in biological systems further, we can observe that cycling within systems enables feedback or "reward" loops to replenish and rekindle ailments, as well as to preserve stocks. Diversity provides a richness of feedback, and a consequent lessening of rigid dependence as discussed above. Odum again, for example, notes that "the most stable of the natural systems have great diversity in many complex species", and that "... insulating mechanisms [are] greater when networks are complex". Furthermore, this variety is essential to an evolutionary process: it is only from the stock of what exists that the new ideas - the mutations - can emerge. The greater the diversity, be it of life species or of technologies, the larger the "library" from which these evolutionary opportunities can spring.

Adaptability registers success in changing to suit prevailing conditions. Here, the ecological concept of succession is a useful tool for thinking about designing and reshaping communities. The process of succession results in increasing diversity toward a stable "climax" state incorporating a richer array of "trophic" (nutritional) levels. It is a process of building upon what exists, rather than tearing down and starting anew. Changes occur constantly but these are normally accommodated as adaptations to the system - adaptations which contribute to the ultimate overall strength and persistence of the system rather than pose as an alternative to its existence.

These matters are well established in the natural sciences but their application to the industrial world is as yet in its infancy, though the infant is beginning to walk. Here are some of the first steps.

John and Nancy Todd attempt to couple their understanding of natural processes to the challenge of creating an enduring built environment. They believe that biology should be the model for design, a basis from which the New Alchemy Institute has, for 12 years now, produced an exemplary stream of work.

Christopher Alexander and his colleagues refers to "organic order" to explain the charm and durability of the older sections of towns and cities which seem to them "live". They propose a pattern of civic development that parallels the ecological concept of succession. They call it "piecemeal growth", a process which they describe as growth-in-small-steps. They have applied this approach to a master plan for the University of Oregon. In describing it as ... "the balance between the needs of the parts and the needs of the whole", they affirm the complex inter-connectedness that is at the root of resilient systems. He and his colleagues enlarge upon this concept with a collection of 253 "patterns" demonstrating in great detail the complex interactions of successful (living) built environments.[9]

The clearest transgressions of this principle of graceful failure in present society are ones of scale and centralization. Amory and Hunter Lovins have documented the lack of grace with which such systems can fail. They characterize them as "brittle". Resilient systems on the other hand are more likely to be associated with qualities of smallness and decentralization. Using the biological sciences as their foundation, the Lovins describe twelve (12) principles directed "toward a design science for resilience." By way of introduction they state that:

"It cannot be overemphasized that the property being sought when one designs a system for resilience is that it be able to survive unexpected stress: not that it achieve the greatest possible efficiency all the time, but that it achieve the deeper efficiency of avoiding failures so catastrophic that afterwards there is no function left to be efficient".[10]

The British biologist J.B.S. Haldane, discusses size; in particular correct size. He observes that an entity whose weight increases three-fold is only blessed with a two-fold increase in the section of its structural components. In such instances he postulates collapse: ..."just as there is a best size for every animal, so the same is true for every human institution".

E.F. Schumacher writing in "Small is Beautiful" has a lot to say on the subject of size. In particular he believes that there is a "...duality of the human requirement when it comes to the question of size: there is no single answer. For his different purposes, man needs ... both small and large [structures]". Later he poses the fundamental task as "... to achieve smallness within large scale organization", and advances five principles toward a theory of large scale organization. Central among these is what he terms the "principle of subsidiary function" - which enables a more humane and efficient organizational state in which freedom and responsibility of the lower formations is carefully preserved.

Hazel Henderson notices that risks are attached to centralized systems. “Each time such risks are socialized at a higher level of societal management, there is a greater aggregation of risks into

[9] C. Alexander et al. [1977] “A Pattern Language: …”, Oxford.
[10] A. & H. Lovins [1982] “Brittle Power, Brick House. p. 191.

fewer, larger units [and such] agglomerations of risks grow more unwieldy"[11]. Therefore, as a third fundamental principle of sustainability, a system must display resilience and adaptability. It must be capable of responding to perturbations incrementally - absorbing impacts, containing the traumas, and repairing malfunctions along with its normal pattern of growth.

Whereas the foregoing affirms the virtue of complexity in a resilient system capable persistence and durability, the next principle views complexity in a human societal context, as an inhibition to sustainable practice.

Principle of rational transparency[12]

If a system should fail at first gracefully by virtue of the attributes it possesses to minimize the initial calamity, its failure is likely to escalate unless the initial fault is repaired. Systems should therefore be repairable. Further, they should not be so opaque to human common experience and understanding as to yield only to specialist intervention because at this point creative opportunity is curtailed and so therefore is the zest for living. This does not mean that everyone should be able to do everything, or that everything should be restricted in comprehension to the understanding if those least mentally primed among us. It simply means that system designers should aspire to embrace rather than eschew the common understanding. It is, as Schumacher says, "...methods and equipment [being] compatible with man's need for creativity". Ivan Illich used the word "convivial" to prescribe technology in compliance with this principle. Amory Lovins and others have used the word "accessible" in conjunction with "soft technology" to mean much the same. Simplicity in this context actually does not represent an antinomy with the previous principle: it allows an interesting reflection. The complex inter-connectedness of the biological world contrasts sharply with the simple standardization of its building blocks: (four elements carbon, hydrogen, oxygen, and nitrogen compose all but 1% of living things). A telephone, one the other hand, embodies 42 of the 92 elements provided by nature.

This principle, therefore, requires that systems be comprehensible to those who use them. It should be the end-users who, as far as possible, are responsible for those systems' development and maintenance.

In terms of things, issues of accessibility and demystification are paramount. Here, simplicity rather than complexity is the virtue. Design that places premium upon simplicity, durability and reparability upholds this principle: design that promotes consumption by constantly changing models with specialized components and limiting supplies of spare parts, etc. is not. Industrial designer Victor Papenak in his book entitled "Design for the Real World" offers a wealth of examples of both.

---

[11] H. Henderson [1981] "The Politics of the Solar Age", Anchor, p.337.
[12] I am indebted to Richard Hatch ("The Scope of Social Architecture") for invention of this phrase, though I have put it in service of a slightly different cause.

Wood stud frame construction is an example of technology consistent with this principle. It is essentially a vernacular technology, unrestricted by specialist expertise. It is capable of accommodating innovation and specialization without excluding the layperson. The same system that has incorporated prefabrication of building panels, structural components such as trusses and pre-cut framing members, boxed stair sections, window and door assemblies, insulation and air-sealing routines, etc. still allows a homeowner to do week-end repairs, talk cogently to a contractor, or to build his or her own house if time and circumstances allow. This is an accessible system. It is a vernacular construction technology, which as, John Harbraken observes, has "become a shared property in the minds of the people".

In terms of institutions, issues of control and accountability are paramount.

The English architect, John Turner and his colleagues have a wealth of project experience attesting to the proposition that "when dwellers control the major decisions of their housing both the process and the living environment produced stimulate individual and social wellbeing: [sustainable]. When dwellers have no control nor responsibility for key decisions in their housing process, dwelling environments may become a barrier to personal fulfillment and a burden to the economy: [unsustainable]."[13]

Christopher Alexander, in various published works and constructed projects over 15 years, deals with the overall organization and production process as it relates to building. He asserts that "fundamental human need(s) [are] to create and to control". This is a theme which is crucial to him. He is concerned that "the decisions which control the form of houses are almost all made at a level too remote from the immediate people and site to allow reasonable and careful adaptation...", and that the quality of housing suffers unutterably as a result. For a housing project at Mexicali, Mexico, he and his colleagues posed seven principles to guide local/user participation and control of the building process, and to develop a framework for a creative civilian workforce.[14]

David Morris & Karl Hess address control in terms of self-reliance "...with all the diversity and resultant flexibility." Self-reliance is seen as a source of strength and cohesiveness, as well as engendering an overall emphasis on productivity rather than dependent consumption. "If there is to be a free society, there needs to be a supporting material base [which] would have to be one in which people generally could develop, deploy, and maintain the tools of every day life and production."[15]

Sustainable systems, be they human institutions or the technologies that service them, should expand their opportunity for human involvement so as to maintain personal identity and self worth of individuals and self-managing groups. They must be so as to encourage individual to accept

[13] J. Turner [1972] "Freedom to Build", Macmillan, NY p. 241.
[14] C. Alexander [1982] "The Production of Houses" Oxford.
[15] Various publications of the Institute for Local Self Reliance, Washington, DC.

responsibility for their actions, rather than engage in the "pathological diffusion of responsibility"[16] so typical of large, unwieldy social systems.

Therefore, the principle of rational transparency, as a fourth basic requirement of sustainability, requires that a system be penetrable to common understanding - supporting and breeding self reliance and self esteem at all levels of social strata.

The principle of common heritage

A sustainable system should acknowledge the global family of mankind by encouraging the continued exchange of information (as opposed to energy and materials) through which the culture of civilizations has evolved. Such regional/global interaction should proceed as a super-ordinate system of contact and information exchange, and may be viewed as a layering of multiple communities-of-interest, (as opposed to the communities-of-locality more properly disposed to the decentralized management of materials and energy). To this extent this principle militates against self-sufficiency (which is seen as a closed system impervious to outside contact) and in favor of self-reliance (which is seen as a state of continued interaction with the world around, but from a position of relative strength and independence).

Within this super-ordinate system, the impacts of individuals and communities may be characterized as the ripples emanating from the plop of a stone in a pond - locally intense and diminishing with increased distance from the epicenter. In this way the system maintains patterns of coherence consistent with the third principle while responding to that peculiarly human need to communicate and exchange information.

Implicit in this principle of common heritage is the practice of fairness and equity in the distribution of opportunities and responsibilities for the use of nature's resources.

How much is enough? The discussion of the first principle beseeched us to examine our needs critically. These judgments must be further conditioned by obligations to share limited resources with those of future generations as well as with the poorest of present humanity. In this context Kenneth Boulding offers the observation that "...the welfare of the individual depends upon the extent to which he can identify himself with others, and that the most satisfactory individual identity is that which identifies not only with a community in space but also with a community extending over time from the past into the future."   A third category of consideration and obligation must be added if the subject is to receive complete coverage, and that is other planetary life.

Consider firstly our obligation to those yet unborn. Their share of solar energy is inalienable. However, the capital stocks of energy and elemental material concentrations in the earth's crust

[16] Hazel Henderson, op. cit. p. 337.

are a depletable asset. Every imprudent act of consumption in this age means fewer opportunities for some future generation - and possibly fewer future generations.

What of the poorest of humanity? If the practices so far outlined whereby sensitive and sensible uses of natural resources are pursued in more decentralized less inter-dependent groupings, then these folk may be better able to advance themselves as they disengage from the power struggles between those who wish to control them and their natural resource base. It is quite clear for example that by preferring to build with local materials, or by farming with less oil, we can increase our own self-reliance simultaneous with relieving the pressure upon others (some less fortunate than ourselves) to contribute their resources to our ends. Values that place emphasis on higher needs, together with a less inter-dependent global structure, will be a disincentive to greed and therefore provide a less dangerous world. Reducing parochial violence bred from envy and discontent is, in a nuclear age, clearly an important route toward a sustainable society.
Finally, our obligation to other planetary life and natural systems are here considered to be in accordance with their instrumental value in an anthropocentric schema.

The principle of natural order

A sustainable system is truly empowered to the extent that it embodies an aesthetic quality that inspires those in contact with it, and those who have the power to remove it if it offends, or if it becomes expedient so to do.

No prescription for the attainment of this state, or the qualities exhibited upon attainment, is given. It may be sought in the contrast of opposites, by the application of corporal proportion, or by the (accelerated) patina of the on-set of ruination. It may be the intricacy and mystery of life forms - their vital geometry and organic order - that pilots the designer. It may be realized in the physical embodiment of its presence, by the joyous affairs of its construction, or the intrigues of its uses — its life-space.

However this inspirational quality be achieved, and whatever it be called, the long life of anything created which attains this state is assured.

A thing of beauty is said to be a joy forever, and “forever” is a very long service lifetime.

The principle of sacred situation

Evidence of this essential quality in a sustainable setting is still accumulating - or being rediscovered. To the deterministic western industrial mindset, it is an open door through which, for the moment, we do little more than look. To the extent that paradigmatic shift from our deterministic ways is required of us in order to fully embrace a sustainable lifestyle, we will in time proceed through the door by enlarging our collective consciousness. But that will truly be "one giant step for [westernized] mankind". Charting those steps is well beyond the scope of this paper. However, the view through the door is both intriguing and compelling.

Glimpses reveal intriguing possibilities. We are beginning to see connections between the obvious permanence of great monuments such as Chartres cathedral and the geomantic determination of its ideal situation (whether viewed in terms of intersecting ley lines or viewed in terms of extremely weak electro-magnetic fields). Evidence of the manner in which living organisms respond to electro-magnetic fields is accumulating. German engineers have used geomantic principles to situate transport arteries with apparently measurable reduction in the incidence of traffic accidents. Well drillers regularly employ dowsing techniques to locate water — without being able to explain why it works. The Chinese "art" of Feng-Shui has a long tradition of determining the right place for things.[17]

The view is compelling because — beyond the possible physical explanation of these phenomena that suggests ideal situation — there is the argument that western thought is an incomplete epistemological structure for thoroughly embracing propositions of human ecological sustainability.[18]

[17] The foregoing was compiled from discussion with Paul Deveraux, a Welsh student of leylines; the magazine of the American Dowsing Society; N. Pennick, “The Ancient Science of Geomancy”; R. O. Becker, [1985] “The Body Electric”, Quill.

[18] See for example the writings of Gregory Bateson; and D. Worster, [1977] “Nature’s Economy: A History of Ecological Ideas” Cambridge.