Sustainable Buildings

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Abstract

"Sustainability" has been defined variously, as was clearly illustrated at the recent United Nations Earth Summit in Johannesburg. When discussed in the context of the impacts of buildings on the environment, its meaning is ambiguous and often distorted. Buildings are not either "sustainable" or not. No buildings being built today are sustainable in the true sense of the word. While many guidelines exist for guiding design to improve building environmental performance, most of the available guidelines do not assess the total impact of a building on the environment. Instead, they tend to rate buildings on the basis of individual features considered "green" or "sustainable" by the designers. A more rigorous approach to assessing building sustainability is needed in practice. Such an approach evaluates a building by its total effect on the environment, not by the number of discrete "green" maneuvers it makes. Some software tools exist that can support decision-making to design buildings based on rigorous analysis of the environmental impacts. Finally, the assessment of a building's impacts on the environment must be related to goals for meeting local, national, and global environmental needs. Such goals can be established and used as benchmarks for building performance. These procedures can be used with available design tools to create new buildings and to evaluate existing buildings on the basis of their projected total environmental performance. When such tools are routinely used we will learn enough to make wise decisions and create buildings that are more sustainable.

Introduction

Everyone who considers their building design services or product "green" *knows* what green is. Nearly everyone else is left wondering.

There is widespread and apparently growing interest in protecting the environment, especially in schools and in local, state, and federal government buildings. Designers are increasingly pressed to design "green" buildings. But how is one to know what is "green"? Is "green" the same as "sustainable." The terms are often used interchangeably. In general, the meaning is vague and inconsistent among so-called "green" buildings.

Some formal guidelines exist for determining the "greenness" of a building. These have to do with energy conservation, use of recycled materials, reduced emissions of toxic chemicals, and many other specific characteristics. The guidelines generally involve incremental improvements over typical current practice. In general, buildings conforming to these guidelines may be less harmful to the environment than buildings designed without the benefit of such guidelines, but we don't actually know if that is true. And even the best of buildings built today fail to reduce resource consumption and pollution emissions to a sufficient degree compared to the scale of the reductions needed to create truly "sustainable" buildings. It is difficult (if not impossible) to find a building being built today that could be regarded as truly sustainable.

Most green building guidelines are based on designers' judgments about immediately available solutions rather than an analysis of the way a particular building design will actually affect the environmental problems of concern. The available guidelines almost all suffer from the same fundamental flaw – they fail to involve an assessment of the combined impacts of the various individual measures promoted by the guidelines – the actual or projected impacts of the completed building throughout its whole life cycle on the local, regional, and global environment.

As such, the guidelines may reflect good current practice, but few of them even involve best current practice. Most of the guidelines are prescriptive in nature; few of the requirements of such guidelines are performance based.

"Green building" is a *construct* without any inherent or consistent meaning as a label for environmentally responsible building. Everyone who uses the term has their own idea of what it means. As a construct, it is not possible to measure just one characteristic of a building's environmental performance and then decide whether or not it is "green." In fact, many things have to be measured, and few of us would agree on what those many things are. Beyond that, we might not all agree on how important various individual characteristics are. Is air pollution more important than water pollution? That depends on where and who you are. What about global climate change versus species extinction? That is a matter of values, a very personal matter. Should we preserve habitats for endangered species if it means changing or reducing timber harvesting or if it means removing major hydroelectric plants from rivers in the Pacific Northwest?

At the heart of any operational definition of "green" building there needs to be a clear, prioritized, weighted set of environmental goals. And there must be yardsticks available to measure how well a building performs against those goals.

When evaluating a building's "greenness," we must assess the impact of the total building on all the environmental problem categories. It is possible to do this today, but not in California, not even in buildings designed to receive LEED certification and rating. To do such analysis, there is a need for data on many aspects of buildings' resource consumption and pollution emissions that are simply not yet available. Not yet. CADD-compatible software packages have been developed based on life cycle assessment methodologies, but so far this has only happened in and Holland. The software programs are in German and Dutch respectively, and the databases used in them are from those countries. There is a need for such software in English using data from sources of products, materials, and energy used in American buildings. Such tools could themselves then be used to develop guidelines based on a representative set of scenarios. Such tools would provide designers with vastly better guidance than is available in the form of existing green building guidelines.

The very existence and increasingly widespread acceptance and use of many green building guidelines gives the incorrect impression that we know enough about buildings' environmental impacts to provide reliable guidance. The truth is that we simply do not know what the net environmental impact is of buildings that get higher or lower scores using the available guidelines. US Green Buildings Council's LEED Rating System and scores of others exist.

Environmental goals of projects are occasionally explicit but usually implicit. When stated, they often take the form of reducing resource consumption and pollution emissions and, occasionally of reducing disturbance of sensitive habitats. The environmental goals of building projects may differ significantly depending on locale and client.

- Acid deposition is not much of a problem in the Far West but it is a major issue in the Upper Midwest and the Northeastern United States.
- Urban air pollution is a big problem in the major communities in California's Central Valley and along coastal Southern California but not along California's Central Coast (Santa Barbara, San Luis Obispo, Monterey, and Santa Cruz).

- Hydroelectric power generation in the Pacific Northwest is controversial due to the extensive damming of rivers and the resultant impacts on the fisheries. Pacific Northwest electric energy costs are so low that energy conservation measures do not gain much support through analysis using purely economic criteria.
- Water consumption in water self-sufficient regions is not an issue of resource depletion. But what is the impact on air quality and climate and their indirect impacts on the abundance of allergens when abundant water facilitates extensively landscaping in an the otherwise arid climate of Phoenix? Those who moved there historically to avoid exposure to pollen and mold are now victims of the "greening" of the desert.

These and countless other examples of differences in local or regional conditions will have significant impacts on the desirability of various building designs and their operational protocols. Building owners often have particular aspects of the environment that are associated with its needs, products, or image. Thus, priorities have to be established in the context of a particular project location and client. Broad guidelines tend to follow a one-size-fits-all format.

An ideal starting place for creating defensible guidelines is an analysis based on a comprehensive set of environmental concerns and set of targets based on human impacts on the environment. Such targets have been set for large scale development projects and regional or national development, and there are whole books written about criteria used and measurements made in such projects. Building projects can and should be similarly evaluated.

A rational approach to establishing guidelines for environmentally-responsible buildings should start with a set of problems and measures of the impacts of alternative design solutions on each of the problem areas. Too often, solutions are aimed at only one or a small number of problems and may end up working at cross purposes with other solutions for different problems.
Table 1 lists the major environmental problems compiled from a variety of authoritative sources including three major studies by the US Environmental Protection Agency.

Table 1. Major environmental problem categories and their respective scales.

Environmental Problem Category	*Scale*
Habitat destruction / deterioration (Biodiversity loss)	Local/Global
Global warming	Global
Stratospheric ozone depletion	Global
Soil erosion	Local/Regional
Depletion of freshwater resources	Local/Regional
Acid deposition	Regional
Urban air pollution / smog	Local/Regional
Surface water pollution	Local/Regional
Soil and groundwater pollution	Local
Depletion of mineral reserves (esp. oil and some metals)	Local/Regional/Global

Buildings are very large contributors to environmental deterioration. Buildings account for 15% to 45% of the total environmental burden for each of the eight major LCA inventory categories as shown in Table 2. Determining buildings' contributions allows prioritizing generic environmental protection goals (discussed later in this article). The portion of buildings' environmental impacts is generally consistent on a global scale.

Table 2. Environmental Burdens Of Buildings, U.S.[2]

RESOURCE USE	*% OF TOTAL*	*POLLUTION EMISSION*	*% OF TOTAL*
Raw materials	30	Atmospheric emissions	40
Energy use	42	Water effluents	20
Water use	25	Solid waste	25
Land (in SMSAs)	12	Other releases	13

The Dutch Concepts of "Ecocapacity" and "Ecospace"

A set of target values for environmental resource consumption and pollution can easily be derived. While such targets themselves are subject to human judgment, they can reflect the best available science, and if the methodology is transparent, as it should be, the targets can be revised as new information arrives. The Dutch government-commissioned a study to propose just such goals in order to move Dutch technology toward sustainability over a 50-year time frame. The authors assumed that all humans are entitled to the same amount of environmental resources and to contribute an equal share of pollution –- that is, each inhabitant is entitled to the same "*ecospace*." They established some "ecocapacity" limits on basic resource consumption and pollution emissions, then calculated ecospace targets for 50 years in the future. The authors allocated environmental resources among nations and calculated the Dutch share. Then, working backwards, they calculated reductions necessary in current consumption and pollution to achieve sustainability. Their informative results are presented in Table 3.

The Dutch authors point out that there is a 30 to 1 disparity in resource consumption and pollution emissions shares between inhabitants of OECD (developed) nations and developing nations or between "north" and "south." The authors propose to reduce the ecospace disparity by a factor of 3 to a ratio of 10 to 1 during a 50 year planning time frame. They do not propose how such a shift toward universal environmental equity should be accomplished, but they based their analysis and projections on assumptions that such a shift was desirable.

The Dutch project that their carbon dioxide emissions must be reduced by 80% in the next 50 years. Using their method, we calculated reductions in per capita energy consumption in the necessary by the year 2050 for us to share equally with all the earth's projected 10 billion inhabitants. Just in terms of carbon dioxide and equivalent other greenhouse gas emissions, Americans must reduce current per capita consumption by more than 95%. Reductions of 80 to 95% are necessary in several other categories. Some consumption, such as copper, for example, will not have to be reduced much if a large fraction of the copper in use is recycled and, therefore, the proven reserves are not likely to be stressed in the foreseeable future.

Setting Targets for Building Environmental Performance

The decision-maker must divide up and allocate the global, regional, or local "ecospace" for each problem being addressed depending on the type of problem:
1) on a per capita basis, determine how much of a building's use is allocated to a given number of people, or
2) on the basis of annual units of building use per person (person square meters per year), or
3) on the fraction of the building type accounted for by the particular building (x percent of all school or office or residential etc. space in the local (or regional or global) community

There are some important issues with each of these three approaches that need to be addressed in the details of their implementation. One of them, for example, is what's called "normalization." This involves trying to create equivalencies so comparisons aren't distorted. There are questions of social justice. For example, if one person occupies a 100 square meter apartment in Helsinki and another person shares a 100 square meter apartment with three other family members, how is ecospace for the kitchen allocated? That is resolved by deciding what you want to do about "environmental justice" and what you want to do about "social justice."

Table 3. Sustainable versus expected level of environmental impact for selected indicators.

Dimension/indicator of environmental impact	***Sustainable level***	***Expected level 2040***	***Desired reduction***	***Scale***
DEPLETION OF FOSSIL FUELS:				
* oil	stock for 50 years	stock exhausted	85%	global
* natural gas	stock for 50 years	stock exhausted	70%	global
* coal	stock for 50 years	stock exhausted	20%	global
DEPLETION OF METALS:				
* aluminum	stock for 50 years	stock for >50 years	none	global
* copper	stock for 50 years	stock exhausted	80%	global
* uranium	stock for 50 years	depends on use of nuclear energy	not quantifiable	global
DEPLETION OF RENEWABLE RESOURCES:				
Biomass	20% terr. animal biomass	50% terr. animal biomass	60%	global
	20% terr. Primary production	50% terr. primary production	60%	global
Diversity of species	extinction 5 species/year	365-65,000 species/year	99%	global
POLLUTION:				
Emission of CO_2	2.6 Gigatons carbon/year	13.0 Gigatons carbon/year	80%	global
Acid deposition	400 acid eq./hectare/year	2400-3600 acid eq. /ha./year	85%	continental
Deposition nutrients	P: 30 kg. per ha. /year	no quantitative data	not quantifiable	national
	N: 267 kg. Per ha./year	no quantitative data	not quantifiable	national
Deposition of metals:				
* deposition of cadmium	2 ton/year	50 tons/year	95%	national
* deposition of copper	70 ton/year	830 tons/year	90%	national
* deposition of lead	58 ton/year	700 ton/year	90%	national
* deposition of zinc	215 ton/year	5190 ton/year	95%	national
ENCROACHMENT				
Impairment by dehydration	reference year 1950	no quantitative data	not quantifiable	national
Soil loss through erosion	9.3 billion ton/year	45 to 60 billion tons/year	85%	global

If one house is very energy efficient but very large and another is very energy inefficient but very small, and if both are occupied by the same number of people and use the same total amount of energy, is the small, inefficient house dweller to be penalized for having an inefficient house? Many of the issues are non-trivial. In the end, as is the case with most things, it's a matter of values. For the design process, what is important is that these questions be considered and resolved as part of the basis for making the many trade-offs that inevitably must be made. There may not be one single “correct” way to do this. But it must be done, and the assumptions and methods must be explicit in order for us to be able to evaluate the results.

Conclusion

Specific environmental impact target-setting can provide benchmarks that enable us to evaluate a building’s total contribution to environmental stress in quantitative terms. Using life cycle assessment tools in conjunction with CADD software, every decision can be evaluated in terms of the total building projected impact on the environment throughout its life cycle. By making explicit our view of the relative importance of different environmental problems in the context of a specific project, we can provide a framework for consistent criteria to be used in evaluating building environmental performance during the design process or in existing buildings. Using a “Building Ecology” perspective - comprehensive, science-based analysis can inform our designs so that we are able to move toward sustainability. All that is lacking is the will to do so.
See, for example, http://www.usgbc.org/Resources/links.asp#3, or http://www.lib.berkeley.edu/ENVI/GreenAll.html

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