RADICAL SUSTAINABLE CONSTRUCTION: ENVISIONING NEXT-GENERATION GREEN BUILDINGS

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Summary
The rapid increase in green building activity in the US over the past 5 years is a sign that sustainable construction is taking root. As of March 2005, over 22 million square meters of buildings had been registered as green buildings under the US Green Building Council's building assessment standard, Leadership in Energy and Environmental Design for new construction known (LEED-NC). A proliferation of LEED assessment standards for other types of construction are emerging. LEED for Existing Buildings (LEED-EB) and LEED for Commercial Interiors (LEED-CI) are now in use. In spite of the major success of the green building movement in the U.S. in the past 10 years, its long-term success is by no means assured. The current suite of green building standards are based on existing materials and methods, design tools, and fee structures. True innovations have difficulty emerging for several reasons: (1) there is no well-recognized definition of a green building; (2) general approaches for green buildings have not yet been established, for example, closing materials loops, passive design, building hydrologic cycle optimization, and integration with natural systems, to name but a few; and (3) there are no specific goals or targets for green building performance. This paper addresses the future of the green building movement and suggests that enormous changes in approaches, here referred to as *radical sustainable construction*, are needed to produce what can be truly referred to as green buildings.

1. Introduction
In countries with successful green building programs, architects, engineers, and builders are employing largely existing methods and simulation tools, and off-the-shelf technologies to design and construct facilities with lower environmental impact, reduced resource consumption, and significantly improved interior environments. Although new tools, materials and systems are beginning to emerge to serve this marketplace, the pace of development is slowed by a lack of a strategic vision for green buildings. In 1998, in the United States, the U.S. Green Building Council (USGBC) developed the first version of the Leadership in Energy and Environmental Design (LEED) building assessment system to guide the design of green buildings. LEED relies largely on existing standards and incremental changes, rather than radical shifts, in design and construction methods for the purpose of creating high-performance buildings. Although it is clear that LEED results in the creation of environmentally improved buildings, it is much less clear in what direction it and other similar standards are directing green buildings. It is also uncertain as to what strategies should be employed to produce the next generation of green buildings and indeed what the desired outcomes of future green buildings should be. This paper suggests several major considerations that should be included in the development of future versions of LEED and other similar building assessment systems to insure the next generation of green buildings, those that will be designed and built in two decades, far more closely represent truly green buildings. The ideal green building should have five major features: (1) Integration with local ecosystems, (2) Closed loop materials systems, (3) Maximum use of passive design and renewable energy, (4) Optimized building hydrologic cycles and (5) Full implementation of Indoor Environmental Quality measures. These future green buildings, here referred to as 'radical' green buildings, should provide significant improvements on today's first generation green buildings. Compared to present generation green buildings, radical green buildings should be far more integrated with ecological systems to create a synergistic relationship between human and natural environments. Natural systems can process waste, uptake stormwater, assist with heating/cooling,

create natural amenity, and provide calories in the form of food. Radical green buildings should also be comprised of materials and products that are reusable and recyclable in a deconstructable building. Greatly reduced energy and potable water use, perhaps by as much as Factor 10, are required for buildings to sustain their consumption of energy. Finally, radical green buildings should integrate all Indoor Environmental Quality measures, to include air quality, noise and sound control, temperature/humidity, light quality, and odor control, into an integrated approach.

2. Green Building Progress in the US as an Example

The rate of growth of green buildings in the U.S. has been nothing short of astonishing. As noted in Table 1, since 1998 the number of registered green buildings using the LEED building assessment system has increased from 0 to almost 1800 and the number of certified green buildings has increased from 0 to 180. In the vernacular of the USGBC, a building is considered *registered* if the project team or owner has formally applied to the USGBC to have the building rated and has paid the appropriate fees. A *certified* building is one that has completed the entire journey through design and construction, all paperwork required for assessment has been filed with the USGBC, and the USGBC has notified the owner of the final level of performance (platinum, gold, silver, or certified). Until recently the LEED building assessment system was comprised of one version, LEED for New Construction (LEED-NC). As of February 2005 there are now two other versions of LEED available for use on projects: LEED for Existing Buildings (LEED-EB) and LEED for Commercial Interiors (LEED-CI). Table 1 also includes other pertinent information about green building progress in the US. The USGBC provides training for building industry professionals and as indicated in the table, over 23000 have attended classes on LEED or other aspects of green buildings. The USGBC also accredits professionals in the application of LEED to building projects and over 19000 have been officially recognized as LEED Accredited Professionals (LEED-AP). It is estimated that 1 to 5% of all new commercial/institutional building projects in the US are LEED registered or certified. The USGBC fully expects even more explosive growth in the future as the LEED-EB system, which addresses greening the vast stock of existing buildings, takes root.

Table 1 Green Building Progress in the US Using the LEED Suite of Standards as a Measurement (As of March 2005)

LEED METRICS*	**2005**	**2004**	**2003**	**2002**	**2001**	**2000**	**1999**
NC Registrations+	1794	1733	1061	603	312	45	0
NC Certified Projects	180	167	82	38	5	0	0
NC Total million m^2	>22	>21	>14	>8	5.1	0.1	0
EB Registrations+	19	6	0	0	0	0	0
EB Certified Projects	14	12	2	0	0	0	0
EB Total million m^2	>0.9	>0.1	0	0	0	0	0
CI Registrations+	21	8	0	0	0	0	0
CI Certified Projects	24	21	0	0	0	0	0
CI Total thousand m^2	>68k	25	0	0	0	0	0
Total Workshop Attendees	22,821	22,495	14,606	7,905	NI	NI	NI
NC Accredited Professionals	19,342	19,200	5,978	2,443	NI	NI	NI

*Cumulative, includes previous year's data; e.g. 2002 includes 1999-2002
+Number of registrations does not include pilot projects.
NI = No Information

In addition to buildings that utilize LEED for measuring their performance, there are probably a substantial number of buildings that have been designed and built using other green building standards, notably in the area of residential construction. A wide variety of residential green building programs exist in various regions of the US, each created by local homebuilder associations or local government. Although the precise number of buildings affected by these programs is not known, it is probable that it is a substantial and growing fraction of new home construction in the US. In addition to the proliferation of residential green building standards, LEED itself has been modified by certain agencies. The US Army, for example, has created a version of LEED known as SPiRiT, that addresses many of the unique situations found on military bases.

3. Shortcomings and Limitations of Current US Green Building Standards

An examination of the LEED-NC building assessment standard is instructive in understanding the state of the art of green buildings. LEED-NC has six different categories with points as indicated in Table 2 and the LEED-NC 2.1 ratings corresponding to various point ranges is indicated in Table 3.

Table 2 Categories and Points Structure of LEED-NC 2.1

LEED-NC 2.1 Category	Maximum Points
1. Sustainable Sites	14
2. Water Efficiency	5
3. Energy and Atmosphere	17
4. Materials and Resources	13
5. Indoor Environmental Quality	15
6. Innovation and Design Process	5
Total Possible Points	**69**

Table 3 LEED-NC 2.1 Ratings

LEED-NC 2.1 Rating	Points Required
Platinum	52-69 points
Gold	39-51 points
Silver	33-38 points
Certified	26-32 points
No Rating	25 or less points

The LEED-NC standard (version 2.1 is the most recent issue) is rigid with respect to points, categories, and ratings and as is the case with the other LEED standards, is considered a ‘one size fits all’ approach to green building assessment. There is not a weighting system based on climate, biogregion, and other factors. Consequently buildings in Alaska and Florida are rated in virtually the same fashion, although the majority of the energy points are a function of location. Buildings in desert climates in locations such as Nevada and those in relatively water-rich states such as Louisiana have a maximum of 5 points allocated for water efficiency. LEED-NC is not based on what might be called a scientific approach for its structure. The categories, points, and ratings are based on the consensus of the committee that developed it. The actual points within each LEED category are also highly arbitrary. Table 4 shows the points allocated in the Materials and Resources category. The point structure is based primarily on materials reuse, use of recycled content materials, and the use of local materials. It does not use life-cycle assessment (LCA) or other technical approaches to assist in the decisionmaking process. Although it does at least partially address closing materials loops, it falls far short in this respect. It does not, for example, address the future extraction of resources from the building and it barely addresses the composition of the products that comprise buildings. Although sustainable forestry is certainly an important issue, this point, as is the case with several others, is subject to a certain amount of gamesmanship in which products are specified solely for the purpose of achieving this point. The strength of LEED is its relative simplicity and ease of use. Unfortunately this is also probably its major shortcoming. Using LEED, a green building can be designed and built with no understanding at all of the rationale for green buildings.

Table 4 Points Allocated in the Materials and Resources Category of LEED-NC 2.1

Materials and Resources: 13 Possible Points		
Prerequisite 1	Storage & Collection of Recyclables	Required
Credit 1.1	Building Reuse (Maintain 75% of Existing Shell)	1
Credit 1.2	Building Reuse (Maintain 100% of Shell	1
Credit 1.3	Building Reuse (Maintain 100% of Shell and 50% Non-Shell)	1
Credit 2.1	Construction Waste Management (Divert 50%)	1
Credit 2.2	Construction Waste Management (Divert 75%)	1
Credit 3.1	Resource Reuse (Specify 5%)	1
Credit 3.2	Resource Reuse (Specify 10%)	1
Credit 4.1	Recycled Content (Specify 25%)	1
Credit 4.2	Recycled Content (Specify 50%)	1
Credit 5.1	Local /Regional Materials (20% manufactured locally)	1
Credit 5.2	Local/Regional Materials (of 20% above, 50% harvested locally)	1
Credit 6	Rapidly Renewable Materials	1
Credit 7	Certified Wood	1

4. Key Strategies for Radical Green Buildings

As noted above, several key strategies that should be standard practice future green buildings include (1) Integration with local ecosystems, (2) Closed loop materials systems, (3) Maximum use of passive design and renewable energy, (4) Optimized building hydrologic cycles and (5) Full implementation of Indoor Environmental Quality measures. The following sections describe how each of these elements can be implemented in next generation green buildings.

4.1 Integration with Local Ecosystems

One of the strategies that can have relatively large benefit-cost ratio for green buildings is extensive integration of ecosystems and landscape with buildings. Ecosystems have the potential for assisting the heating and cooling of buildings, storing stormwater, providing wastewater treatment, providing for calorie (food) production, serving an artistic function, and providing environmental amenity (Kibert, Sendzimir, and Guy 2002). Although integration of ecosystems with buildings has been tried on a limited basis, there are few if any cases of the full integration of landscaping with the built environment. The actual approach to ecosystem integration will vary greatly depending on the bioregion, the character of local ecosystems, local weather patterns, development density, the character of local soils, and other factors. Consequently it should be expected that integration of built and natural environment will vary greatly around the world and that the potential level of integration will also vary depending on a wide variety of factors.

4.2 Closed Loop Materials Systems

One of the key strategic goals of any sustainable construction effort must be the closing of materials loops. This is a daunting task because it means that buildings will have to designed for deconstruction and all products comprising the building must be able to be disassembled into their constituent materials. Clearly the products must be reusable or the materials comprising the products must be recyclable. Thermodynamics dictates that some level of material waste will be created in manufacturing and recycling and this waste must have be harmless as it dissipates into the environment. Finally the extraction, production, and use of resources must be harmless throughout the entire process, including materials dissipation at each stage in the materials cycle.

4.3 Maximum Use of Passive Design and Renewable Energy Systems

Few green buildings today are climate responsive, that is, take advantage of local renewable energy sinks and sources, to include solar, wind, rain, groundwater, and the earth in the vicinity of the building. Passive design is only minimally implemented. In fact, buildings should be fully integrated and designed to be heated, cooled, ventilated, and lighted by local resources. New design strategies and integrated tools are sorely needed to assist the creation of far more effective passive building designs. Rather than designing passive heating, cooling, ventilation, and lighting systems separately, tools that simultaneously address the whole building performance are needed to implement what might truly be called *systems thinking*.

4.4 Optimized Building Hydrologic Cycles

Potable water is in short supply in most areas of the world and the cost of processing wastewater continues to escalate due to rising infrastructure and energy costs. Additionally in many locales, stormwater handling and processing is technically difficult and expensive. Present design approaches address water supply, wastewater, and stormwater as separate issues rather than in an integrated fashion. Current generation green buildings utilize ultra low flow fixtures as the primary means of reducing potable water consumption. A limited number are incorporating rainwater harvesting systems and graywater systems to further reduce potable water use. The use of natural systems to process wastewater is a greatly under-explored possibility with a huge potential for reducing energy and infrastructure costs as well as developing a synergistic relationship with natural systems where nutrients are provided for the benefit of ecosystems. Similarly the potential for using trees and other biomass for uptaking stormwater is virtually unexplored and, as is the case with natural system processing of wastewater, significant savings in energy and infrastructure are a potential outcome. Another possibility for storing stormwater and processing it in a more natural manner is the use of eco-roofs or 'green' roofs on structures. Again, the problem, as is often the case in implementing sustainable construction, is the integration of disparate approaches into a overall approach.

4.5 Full Implementation of Indoor Environmental Quality Measures

Of all the areas of focus in sustainable construction, the one with the greatest potential payback is attention to indoor environmental quality (IEQ). Preliminary analysis of emerging green buildings in the US indicates a factor 10 or more payback in health and performance of building occupants compared to, for example, energy savings. At present a fully integrated approach to IEQ for green building does not exist. Although the causes of poor building health are fairly well known, an systematic approach to providing the wide range of quality needed for healthy buildings is yet to be developed. This is a potentially complex issue because IEQ includes air quality (chemical and biological), noise, lighting, vibration, views to the exterior, temperature, and humidity.

5. The Issue of Scale

Many optimal approaches to resolving green building issues are not able to be implemented at single building scale. Particularly in urban environments, the employment of natural systems to replace manufactured systems can be challenging because of a scarcity of green space and an absence of significant ecosystem area. For example, the use of wetlands for processing wastewater and/or stormwater depends on significant areas of ecological systems, either natural or constructed, for this purpose. Consequently some next-generations green buildings may require a much larger scale, perhaps as large as a *bioregion,* where large areas of forest and wetlands process waste streams from urban areas in a manner that benefits the natural systems. This approach has many potential benefits: reducing energy and infrastructure costs, reduced use of chemicals for treatment, and benefits in the form of nutrients to natural systems. Similar arguments could be made for the implementation of renewable energy systems where tracts of land are used for wind energy and photovoltaics. It is also possible that natural systems will have a role to play in the so-called "hydrogen economy" where photosynthetic strategies are used to breakdown water to produce hydrogen. In many of the cases describe here the ecological systems that are integrated into a sustainable built environment strategy can provide environmental amenity as well as be a source of food. Agricultural areas could benefit from urban proximity with the flows of nutrients and water from cities benefiting farms, forests, plantations, and other systems providing food and resources for industry. Large scale composting where all organic waste, to include wood, paper, other organic fiber waste, and food waste from construction and demolition activities, as well as from farms, homes, restaurants, and offices are processed into nutrients for use in farming, forestry, urban landscapes and other suitable end uses. The issues of large scale integration of sustainable built environments with natural systems is a little explored area that needs to be further developed to create truly improved building performance.

6. Other Strategies

Several other significant strategies are needed for the design of the next generation of green buildings, those one to five decades into the future. For example, industrial ecology has been making steady progress in the redesign of industrial systems. Indeed most of the products comprising buildings are manufactured by exactly these industrial systems and the lessons learned from the automobile and electronics industry, to name a few, certainly apply to building products.

6.1 Industrial Ecology

First noted as a discipline in 1989, industrial ecology has morphed from its original roots in industrial symbiosis to a broader range of options that include Design for the Environment (DfE). One of the emerging green building strategies for closing materials loops is Design for Deconstruction (DfD) which addresses strategies for building structures with the intention of facilitating component and materials recovery when the structure become technically or economically obsolete. In effect, the industries that manufacture building products should have the same requirements as other industries that have been subjected to regulation such as *Extended Producer Responsibility*.

6.2 Biomimicry

Biomimicy emerged as a concept popularized by Janine Benyus (1997). Biomimicy could be called 'strong ecololgical design' because it advocates using exactly the same materials and processes utilized by nature. The general rule could be stated as: If the material or process is not present in nature, it should not be used in the human sphere. Materials produced by nature are produced locally, breakdown when their useful life is expended, and the breakdown products are used by nature in a continual process of constructing new materials. Nature does produce 'toxins' as opposed to the 'toxics' often created in industrial processes. The difference is that toxins are produced in small quantities, for defensive purposes, and breakdown into raw materials for recycling by nature. In contrast, toxics are generally persistent, are not used for defensive purposes, and may dissipate around the planet, with negative consequences virtually everywhere.

7. Evolving Ecological Design

Virtually every definition of green building includes the statement that ecological design, or a parallel concept such as sustainable design, is essential to the design of green buildings. In fact, ecological design as such does not exist in any coherent manner. There is scant evidence of any attempt to mimic nature, use natural system processes, apply biomimicry, or employ any other measures that in any way relate to ecology. Clearly the ecological background of the vast majority of built environment professionals needs to be reinforced because ecology has not traditionally been a part of their educational process. The result is that it is highly unlikely that any real lessons from nature can or will be part of the design of green buildings. Remedying this deficiency is a long-term process which is yet to begin. As important as understanding ecology is as a prerequisite for implementing ecological design, a newly emerging discipline, often referred to as *applied ecological design*, is equally important. Understanding what lessons from nature apply to the human sphere and the difference between using nature as model or metaphor would greatly benefit the development of ecological design.

As high-performance green building evolves, it is likely that the three basic contemporary approaches will be synthesized into an integrated process and that ecological design will become a part of a new design process. The three contemporary processes alluded to here are: vernacular design, the technological approach, and the biomimetic (based on biomimicry) approach (Kibert 2005).

7.1 Vernacular Design

Vernacular architecture embeds cultural wisdom and an intimate knowledge of place into the built environment. It is technology or applied science that evolved by trial and error over many generations in locations all over the planet as people designed and built the best possible habitat with the limited resources in their locale. With respect to designing high performance buildings, vernacular design is the closest approach to true ecological design available today. A good example of vernacular architecture is the traditional residential design of Florida referred to as c*racker architecture*. In this vernacular form houses and buildings are constructed off the ground, creating flow paths for air around and through the structure, allowing ventilation and conditioning by the prevailing winds. Originating in the early 1800's, the cracker house is well-designed for the region's hot, humid climate, and emulates the *chickee* of the Seminole Indians, a covered structure with open sides, the floor an elevated platform 3 feet above the wet ground, used for dining and sleeping. The galvanized, metal roof of cracker buildings is durable and reflects Florida's daily intense solar radiation away from the structure. The structure is lightweight and energy shedding, and, rather than absorbing energy, reflects it, thereby helping to maintain moderate interior temperatures. Modern cracker architecture buildings retain the appearance of the traditional cracker buildings, with metal roofs, cupolas, and porches, but employ modern technology to meet the needs of contemporary business and homes. As is the case with much of today's vernacular architecture, some of the original features, such as the capability for passive ventilation, are for all practical purposes due to year round reliance on modern HVAC systems. Additionally, although useful for smaller buildings, cracker architecture is difficult to apply to large buildings because the roof tends to become inordinately large and for urban office buildings, the porches can lose their appeal.

7.2 The Technological Approach

In contrast to the Vernacular Vision which uses historical wisdom and cultural knowledge to design buildings, the Technology Approach follows generally along the path of current trends in society. Contemporary society, especially in the developed world, has a love affair with technology. Technological optimism, the feeling that all problems, to include resources shortages and environmental problems can be solved simply by developing new technology, is the prevalent attitude. For buildings, technological solutions revolve around developing new energy technologies such as photovoltaics and fuel cells, and finding technical solutions to the problem of how to more effectively utilize renewable energy sources. High technology windows with spectrally selective coatings and gas-filled panes, control systems and computer systems that respond to optimize energy use based on weather and interior conditions, energy recovery systems that incorporate dessicants to shift both heat and humidity, and materials incorporating post-industrial and post-consumer waste are typical examples of a high technology approach. Contemporary commercial and industrial buildings are equipped with a wide range of telecommunications and computer technologies that challenge even the most intelligent vernacular design approaches, simply because of the needs to remove the large levels of energy generated by the tools of the workplace. Indeed it could be argued that the technology of the building itself must be carefully matched and coupled to the technologies employed by the building occupants.

The Technological Approach to high performance green building is an evolution of current practices. Over time the built environment professions, backed up by experience, research, and the development of better systems and products, will be able to design buildings that are much more resource efficient than today's green buildings and have far lower impacts in their construction and operation. The key characteristics of the ultimate high performance green building are based on incremental improvements in existing technology and are probably unlikely to be radical changes to today's practices.

7.3 The Biomimetic Approach

Popularized by Janine Benyus in her book, *Biomimicry: Innovation Inspired by Nature* (1997), the idea of using nature's designs and processes as the basis for human goods and services, is one that has much appeal when it comes to considering high performance buildings. She refers to biomimicry as "..the conscious emulation of life's genius." A biomimetic strategy, that is one based on biomimicry or imitation of nature, is a relatively recent idea that may provide many of the answers to finding approaches to create the ultimate high performance building. Biomimicry is fundamentally about observing nature and basing materials and energy systems on these observations. Beautiful ceramic seashells are produced at ambient water temperatures from materials in the environment, with no waste, with the result being elegant products perfectly designed for their function of protecting their inhabitants. In contrast, ceramics created by human technology are produced at temperature of several thousand degrees, consuming significant energy and producing emissions to air and water, and solid waste. The materials and resources for production of the ceramics must often be transported significant distances, increasing the energy investment. There are many other examples of biomimicry that can be adapted as safe and sound technological approaches: Nature's ability to convert sunlight into chemical energy via photosynthesis, the phenomenal information storage and transmission capability of nerves and cells, tremendously strong and lightweight materials, powerful adhesives, to name a few. Chrissna du Plessis (2003) described a fanciful future built environment based on a full-fledged implementation of biomimicry in a true, out-of-the-box thought process. All components of the building are biologically based and created from proteins, with solar energy collectors embedded in portions of the structure facing the sun. The structure is strong and lightweight and glued together with powerful adhesives based on those used by mussels to attach themselves to rocks in cold, murky water. Temperature and humidity are regulated by membranes that allow energy and moisture to move in and out of the occupied spaces, with embedded nano-processors controlling the movement. Like all other components, the membranes are self-repairing, self-regulating, and self-cleaning. Waste from the activities and functions of the building's inhabitants is processed by living machines that breakdown waste into nutrients for use in the food gardens, which is also designed to be self-reproducing and diverse, minimizing pests. At the end of its useful life, the entire building is able to be digested with the organic components being cycled for other uses and the mineral and other inorganic materials collected for recycling and reuse.

8. Conclusions

The initial or first stage of sustainable construction has been underway for perhaps 15 year and has made enormous progress. The next stage of evolution will have to cope with significantly higher energy costs, an increased threat of climate change, a still rapidly growing world population, the depletion of key resources, the introduction of thousands of chemicals whose impacts are not well-known, increasing air and water pollution, growing levels of solid waste, and a host of other local and global environmental problems. Today's green buildings, while a dramatic improvement over conventional construction, are rooted in conventional design approaches, existing methods of analysis and design tools, and dependent on off the shelf products and materials. The next generation of green buildings will have to be radically different from today's versions and will be designed using integrated systems approaches that can assist in the implementation of the major approaches suggested here: deconstructable buildings, reusable components, recyclable materials, integration with ecosystems, optimized hydrologic cycles, extensive employment of passive design and renewable energy, and full implementation of indoor environmental quality measures. The research and development to test these concepts at various scales cannot begin soon enough. Clearly the education and training of building industry professionals will have to also accommodate these changes, not only in the realm of high performance buildings but also to broaden awareness of ecology in order to more fully develop the critical area of ecological design. Finally, success in the ambitious endeavor to develop next generation buildings will depend greatly on the collaboration of the vast array of building product manufacturers in designing products that can be disassembled, recycled, and reintegrated into new products.

References

Benyus, J. 1997. Biomimicry: Innovation Inspired by Nature, New York: William Morrow and Company.

du Plessis, C. 2003. ""Boiling Frogs, Sinking Ships, Bursting Dykes and the End of the World as We Know It." International Electronic Journal of Construction, Special Issue on Sustainable Construction, 14 May 2003, online at http://www.bcn.ufl.edu/

Kibert, C. 2005. Sustainable Construction: Green Building Design and Delivery, New York: John Wiley & Sons.

Kibert, C., J. Sendzimir, and G. Guy. Editors, 2002. Construction Ecology: Nature as the Basis for Green Building, London: Spon Press, Ltd.