Sustainability in Architecture

by

Elizabeth Cordero

Bachelor of Architecture
California State Polytechnic University, 1992

SUBMITTED TO THE DEPARTMENT OF ARCHITECTURE IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN ARCHITECTURE STUDIES
IN BUILDING TECHNOLOGY
AT THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

JUNE 2001

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Architecture Studies in Building Technology

ABSTRACT

Current standard practice in architecture does not take into account the external societal costs that a building creates. To understand the total consequences of a building, one must consider all of the ecological and human health factors involved for a specific project and site. The aim of sustainable architecture is to construct a well-designed building and site environment that is healthy for the occupants, has minimal undesirable impact upon the environment, is effective in the use of natural resources, and is economical and durable. Although tangible impacts are visible only after construction begins, decisions made on the drawing board have long-term environmental consequences. The objective of this thesis is to present the information and tools available to the architect to create a sustainable project. With these tools, the architect can meet the challenges of sustainable design with an informed decision making process.

This thesis defines sustainability as it applies to architecture, compares environmental performance rating systems and guidelines, discusses simulation, design, and life cycle analysis tools, outlines specific green building strategies, devises a methodology for prioritization, and summarizes design and construction procedures that incorporate these green concepts into the building process. The thesis finishes with a complete project plan that, when incorporated, will promote the realization of sustainable buildings.

Thesis Supervisor: Leon Glicksman
Title: Professor of Building Technology

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> Building construction, renovation and operation consume more of the earth's resources than any other human activity. Each year, as much as 40% of the raw materials and energy produced in the world are used in the building sector. This generates millions of tonnes of greenhouse gases, toxic air emissions, water pollutants, and solid wastes. No other sector has a greater impact on the global environment or faces a greater obligation to improve its environmental performance. With so much of the world's resources consumed in the building sector, learning how to build with the environment in mind will make a big difference for the global environment.
> ASMI, "The Environmental Challenge in the Building Sector" 1999

Sustainability is an accepted term that has been in use since the early 20th century theory of renewable resource management, most notably in sustainable agriculture and forestry, and in theories of 'sustained' yield. It was at The World Comission on Environment and Development, through the Brundtland Commission's report, *Our Common Future*, that brought this term to the conscience of the general public in 1987.[1] The intent of the Commission was to reconcile the interests of economic development and environmental conservation. While it first focused on biological systems, sustainable theory has been applied to many disciplines.

The term sustainability, as it refers to architecture, must be defined so that a subsequent conversation can progress with a full understanding of its meaning. More than just energy efficiency, it is an ecological approach to design. All the resources that go into a building: materials, fuels, and the understanding of the users needs, must be considered to create a sustainable building. While there are many definitions of sustainability (see end of chapter), it seems to be more of a process than a set of concrete ideas. The basic principles evolve as conditions, ideals, and technological capabilities change. It is the belief carried throughout this thesis that the aim of sustainable architecture is to construct a well-designed building and site environment that is healthy for the occupants, has minimal undesirable impact upon the environment, is effective in the use of natural resources, and is economical and durable. Sustainable design means looking at the building process and design in a holistic manner because each design decision affects another. For example, the choice early in schematic design to use natural ventilation and daylighting will affect the capacity of the HVAC unit specified. In turn, these decisions all have local, global, natural resource, indoor environmental quality, and cost implications. While they all have slightly different meanings, for the purposes of clarity, the terms "sustainable architecture", "green building", "high-performance buildings" and "environmentally conscious design" will all be used interchangeably.

When embarking on a new project, the architect is charged with many tasks and responsibilities. In addition to wanting to create a beautiful and memorable building, they must satisfy a project program, meet all the applicable codes and standards, design a space that is safe to occupy and structurally sound, accomplishing all within time and budget constraints. Not an easy endeavor. But designing sustainably is not to be thought of as just an added task. Rather, it's an entirely new way of looking at the whole design process and therefore, the product: the plan, site and building. In practice, many of the philosophies of green design have been observed for centuries in vernacular architecture. It was thought of simply as common sense. Sustainable architecture, as it is conceived of today, builds on those principles, and adds the technological advances of the modern world. It is an opportunity to design and build a project that is inspiring, timeless, and environmentally responsible.

Why Build Green?

The answer lies in the role the architect plays in the global sense. While it is an exaggeration to say that architecture is solely responsible for global warming, the loss of biodiversity, ozone depletion, deforestation, acid rain, and a myriad of other environmental calamities, buildings do account for 1/6 of the world's freshwater withdrawals, 1/4 of the wood harvested, and 2/5 of the energy and material flow.[2] Buildings also account for about 17% of the world's greenhouse gas emissions[3] and in this nation alone, account for 27% of the total annual electrical supply.[4] Buildings also emit annually 120 million metric tons of air pollutants, such as nitrous oxides, sulfur oxides, volatile organic compounds, particulates and lead.[5]

On a local level, architectural and planning practices can encourage investment in urban environments and existing infrastructure, which can revitalize neighborhoods and leave greenfields and natural sites to be enjoyed in their pristine state. It is out of the scope of this thesis to debate whether these are important issues to which society should focus its attention; I will assume they are. The point is that architects, through the buildings they design, have a major impact on the world in which we live. Further, as it has been estimated that most adults spend as much as 90% of their time indoors,[6] the built environment is a key factor in the way we interact, our health and well-being, and our ability to be productive. At even a more basic level, the homes ánd cities in which live influence the world-views we ultimately formulate. Therefore, the criteria for assessing whether a building is beautiful, or award-winning must be based on issues that include sustainability. This thought is validated by the American Institute of Architects, in a recently passed resolution "to acknowledge Sustainable Design as the basis of quality design and responsible practice for AIA architects, and therefore, to integrate Sustainable Design into AIA practice and procedures."[7]

Another reason to build green includes the economic benefits. A small increase in employee productivity can have a dramatic effect on the operating costs of a company. A study conducted by the Rocky Mountain Institute has shown that a sustainably designed building can increase worker productivity by 6% to 15%.[8] Since payroll costs typically represent about 85% of a businesses operating costs,[8] about 70 times more is spent on salaries than on energy. In another study by the Environmental and Energy Study Institute that looked at student performance in classrooms, the results showed improved test scores of up to 11%, and less fatigue and better classroom behavior of students.[9] Additional tangible benefits of green building practices include:[10]

Project first cost savings through reduction of system requirements, loads and materials efficiencies

Higher developer tenant rent, including rental rates, faster lease-up and increased tenant retention

Enhanced building operating performance and annual operating cost savings (energy, water & waste)

Increased building loan potential and building value due to higher building net operating income

Optimization of employee health and productivity
Reduction in building occupant related illness liabilities
More positive public relations and community support
Decreased environmental impact, including pollution, global warming, waste and resource consumption
Increased local job creation
Possible investment tax credit benefits (States of California, New York legislation, and in the future Massachusetts)

In architecture, as in most businesses, the market is a key driver of decisions. A very powerful reason for architects to design sustainably is that more frequently, clients are asking for green buildings, and many state and federal municipalities are demanding them. On a federal level, the introduction of Executive Order 13101 puts into place the *Strategic Plan of the Federal Government under the new Greening of the Government through Waste Prevention, Recycling and Federal Acquisition.*[11] It defines the vision, mission and goals of the government initiative and establishes agency milestones. Exectutive Order 13123, *Greening the Government through Efficient Energy Management,* focuses on the documentation of employed sustainable measures at federal buildings and sites.[12] These two EO's effectively create a market for sustainable technologies by the fact that emerging green technology companies have a guaranteed customer in place. The General Services Administration, the U.S. Postal Service, the U.S. Air Force, the Foreign Services Administration, and the U.S. Navy have all shown their commitment to a sustainable future by requiring a green building rating for all of their new construction.[13]

Another key element to successfully moving towards a green architectural paradigm is the education of the architect. It is obvious to state that what is valued and taught in our design schools will be practiced by newly graduated students. Only when the education of the student includes issues of sustainability integrated into the design studio, will there be a shift in what gets routinely designed and ultimately built. It is unreasonable to ask the practicing architect to spend his/her own time learning a completely new discipline while still satisfying all the other demands, and unfair to pass those costs onto the client. To help mitigate that problem, there are a number of simulation tools available to aid in the realization of a sustainable project. Some require advanced knowledge and are expensive to use. But there are others that are straight forward and appropriate at the schematic design level.

This topic is further explored in Chapter 3, *Simulation & Design Tools*.

One of the main aspects of sustainability is that there is no single answer or design solution. The use of guidelines and performance rating systems can help one define what is green for a particular project. By guideline documents, we refer not only to technical strategies, which are important, but every to step that ensures a sustainable project. Green building guidelines define principles and identify goals of green building concepts and outline a process by which to realize these goals. This includes a reinvestigation of the whole process of design and construction. While there are many very good guideline documents available, it is impossible for them to be all encompassing. Many city and state municipalities, universities, non-profit organizations, private firms and federal governmental agencies have taken the initiative to draft their own sustainability guidelines. The reason for this is to address their own building types, city codes & regulations, climate & regional concerns, stakeholders' interests, and definitions of 'green'. Each entity has used a different approach in the development of its guidelines or assessment system. And accordingly, they have been written with a different audience in mind, consisting of builders and developers, architects and consultants, government officials and building owners. While it would be useful to be able to refer to a single document, it cannot be done. By their very nature, each entity's guidelines are unique and serve a different purpose. In addition to guideines, for the past several years there have existed environmental performance assessment rating tools such as LEED (developed by the U.S. Green Building Council), and BREEAM in Canada and the U.K. The value of these rating tools is to acknowledge and institutionalized the importance of assessing buildings across a broad range of considerations. They provide a method to ensure that buildings are constructed in an environmentally sensitive manner. Chapter 2, *Guidelines and Rating Tools*, provides an overview of existing guidelines and environmental performance assessment systems, and looks at five specific documents in detail.

One of the inherent problems of rating systems is prioritization; typically points are given for acheiving a task or strategy. But what makes sense for one climate region, building type or even client may not makes sense for another. The strategies employed in the temperate climate of California would not be the same as in New England. Or the process of designing a single family house differs from that of a university building. Someone, or some group of individuals had to predetermine the worth of that strategy. Therefore, for the purposes of establishing an objective methodology to prioritize green building strategies, a survey was conducted using MIT's Green Building Task Force[14] (GBTF) as a platform. The goal was to assess the priorities and long-term environmental goals of the MIT community that could be used to develop the university's mission statement. It comprises criteria and standards of design for green building. This discussion can be found in Chapter 4, *Green Building Strategies*.

Green building guidelines, sustainbility tools and design strategies all contribute to a more sustainable project. But without a planning, design, and building course of action that incorproate these concepts into the building process, many opportunities will be lost. Sustainability presupposes a collaborative interaction amoung all the participants, and a cyclical project delivery process, as opposed to the standard linear model. Chapter 5, *The Building Process,* will look at the phases of design and construction in detail and outline green building activities that are relevant in each phase.

Finally, this thesis outlines a comprehensive plan of action that an architectural firm, corporation, or educational institution could implement that would contribute to the realization of green buildings and campuses in Chapter 6, *Elements of a Project Plan*.

Definitions of Sustainable Architecture

American Institute of Architects
In its broadest sense, sustainability refers to the ability of a society, ecosystem, or other ongoing system to continue functioning into the indefinite future, without being forced into decline through exhaustion or overloading of the key resources on which that system.

Building Services Research and Information Association (BSRIA)
The creation and responsible management of a healthy built environment based on resource efficient and ecological principles.

Carol Cahrmichael, Institute for Sustainable Development and Technology
Sustainable development requires innovative solutions for improving our welfare that are derived from practices and technologies that work harmoniously with earth's systems and across diverse groups of people. "....consider our actions over greater lengths of time." Most interpretations of the terms sustainable refer to the availability of natural resources and ecosystem functioning over many generations, and to the enhancement of human living standards through ecologically sound economic development. The United Nations defined sustainable development as (The UN World commission on Environment and Development, 1987):........development that meets the needs of the present without compromising the ability of future generations to meet their own needs....

Jean-Lou Chameau, Ph. D.
The concept of sustainable development is ethical in nature and requires a conscious choice to provide for the needs of present and future generations.

Bruce Coldham, Architect
First and foremost, a green building serves the need of the people who inhabit it. It supports and nurtures their health, satisfaction, productivity, and spirit. It requires the careful application of the acknowledged strategies of sutainable architecture - nontoxic construction, the use of durable, natural, resource efficient materials, reliance on the sun for daylighting, thermal and electric power, and recycling of wastes into nutrients. An elegant architectural integration of these strategies produces a building which honors the aspirations of those who use it and engages the natural world. And it must be more.

Georgia Tech Institute for Sustainable Technology and Development
"Sustainability" is not a product or an outcome: it is a criterion for guiding decisions in order to help society meet the needs of the present without compromising the ability of future generations to meet their own needs. Sustainability promotes careful judgements about a wide range of impacts of technological development and economic growth, incorporating science and technology, business, social forces and ethical considerations, and policy decisions, ranging fro the community level to the entire globe.

Fred Harris, Harris Originals, Inc.
When applied to buildings, sustainability generally refers to the use of materials that are recycled and recyclable, materials that use resources efficiently, materials that are nontoxic, and materials that are made from renewable resources. It also refers to the process of designing and building is such a way that construction waste is minimized, and the waste that is produced is immediately recycled. Or it can refer to the process of designing and building in such a way that the component parts can be removed without destroying them. This leaves them in good condition for reuse. Smaller spaces used for multiple purposes can help to reduce the building size. Sustainability means reducing the energy consumption of building materials to the lowest level practicable.

Robert Hsin, Florida A&M University
Sustainable design is an ecologically based philosophy which means that the design principles must be all-encompassing, considerate of the whole eco-system. The 'green' architect or planner must be concerned with not only the buildings, but also that of the environment, the resources, the local culture and economy, the materials, and the environment which the materials orginated from.

Integrated Waste Management Board
A green building is a structure that is designed, built, renovated, operated, or reused in an ecological and resource-efficient manner. Green buildings are designed to meet certain objectives such as protecting occupant health; improving employee productivity; using energy, water and other resources more efficiently; and reducing overall impact to the environment.

Jack Kremers, Kent State University
Sustainable architecture describes an approach to architectural design that minimizes sustenance or resource consumption so as to prolong the

availability of natural resources. Sustainable architecture, then, is a response to an awareness and not a prescriptive formula for survival.

Brantley T. Liddle, Center for Construction Research and Education, MIT
Sustainability is concerned with two types of limits the environment imposes on growth or development - source limits and sink limits. Source limits refers to the environment's finite capacity to provide resources-both renewables and nonrenewable, and both mere production inputs and essential, nonsubstitutable "natural" services. The sink limit refers to the environment's capacity to assimilate the wastes that economic growth and development cause.may have implied an extreme approach to building 20 years ago. Now it simply means minimizing the ecological impact of a building. Sustainable design is a balancing act, a matter of concentrating the architect's time and the client's resources on choices that will do the most good.

Nadav Malin, Environmental Building News
A sustainable building starts with the quality of its components, as measured by their environmental impact. There are many variables to take into account while evaluating the components, including the way they will be used, the amount that is specified, and aesthetics.

William McDonough, Architect
Designing for sustainability requires awareness of the full short and long-term consequences of any transformation of the environment. Sustainable design is the conception and realization of environmentally sensitive and responsible expression as a part of the evolving matrix of nature.

John Norton
Sustainable architecture brings together at least five key characteristics: environmental, technical, financial, organizational, social. Sustainable architecture is context specific and relate to the resources that are locally available, or the customs and need of the local population.

The Royal Australian Institute of Architects
Five principles to realizing a commitment to sustainability: maintain, and where it has been disturbed, restore biodiversity; minimize the consumption of resources, especially non-renewable resources; minimize pollution of soil, air, and water; maximize the health, safety, and comfort of building users; increase awareness of environmental issues.

Wendy Talarico, Architectural Record
Green, or sustainable design may have implied an extreme approach to building 20 years ago. Now it simply means minimizing the ecological impact of a building. Sustainable design is a balancing act, a matter of concentrating the architect's time and the client's resources on choices that will do the most good.

Alan Traugott, Flack + Kurtz Consulting Engineers
Sustainable design is a common sense approach to building. The goal is to design a pragmatic building which minimizes pollution output from construction and operations; uses resources, materials and energy very efficiently; is reliable, secure, simple to operate and maintain; has a long, useful life expectancy; provides a highly functional and healthful environment for its occupants.

U.S. Navy
Sustainable design, based on resource efficiency, a healthy environment, and productivity, incorporates the following: increased energy conservation and efficiency and use of renewable energy resources; reduction or elimination of harmful substances and waste in facilities and their surroundings; improvements to interior and exterior environments leading to increased productivity and better health; efficiency in resource and materials utilization, especially water resources; selection of materials and products based on their life-cycle environmental impacts; and recycling and increased use of products with recycled content.

Robert and Brenda Vale, authors of Green Architecture, Design for a Sustainable Future
That a green approach to the built environment involves a holistic approach to the design of buildings; that all the resources that go into a building, be they materials, fuels, or the contribution of the users need to be considered if a sustainable architecture is to be produced.

Notes

[1] World Commission on Environment and Development, 1987. Toward Sustainable Development. Our Common Future, New York: Oxford University Press. Pg 43-66.
[2] Worldwatch Insitute, 1995, Paper 124, A Building Revolotion
[3] Facilities Management Journal, EnvironDesign 2000
[4] Annual Energy Review, Department of Energy, 1993
[5] Asher Derman, PhD, Building Locally, Thinking Globally
[6] Environmental Protection Agency, http://www.epa.gov/iedweb00/
[7] The AIA Sustainable Design Resolution:

1. Revisions to the AIA contract documents, including the standard legal agreement between owners and architects. This will help owners clarify the scope of work that is required to produce more sustainable buildings.
2. Revisions and additional information to Masterspec, the standard specifications system used as a master document by most architects in the US. This will streamline the process of selecting and specifying environmentally preferable products.
3. Support for reserach efforts that quantify the benefits of sustainable design, including the integrated design process and life cycle cost savings. This will help design professionals and their clients make the case for sustainable design.
4. Support for research efforts to develop design tools and educational resources that will support the creation of high performance buildings and the next generation of sustainable design solutions. This action refers to the two primary programs of the AIA Committee on the Environment. We are creating a program to integrate Sustainable Design into the core of college and university Schools of Architecture, and we are outlininga research agenda that will advance our current knowledge base.
5. Advance the knowledge base of information on life cycle environmental effects related to building products and materials. By lending the support of the AIA as a whole to these efforts we hope that they will receive the funding necessary to be completed.
6. Support the consideration of sustainable design in the AIA Design Awards program. This is a logical next step that is needed to provide recognition to exemplary projects, and to reinforce our broad definition of quality design.

[8] Rocky Mountain Institute, *Greening the Bottom Line, Increasing Productivity through Energy-Efficient Design,* by Joseph Romm and Bill Browning, 1994
[9] Cited in Environmental and Energy Study Institute, *Energy Smart Schools: Opportunities to Save Money, Save Energy and Improve Student Performance,* November 1999
[10] Worldwatch Institute, 1995, Paper 124, "A Building Revolution"
[11] Executive Order 13103 - Section 401. Acquisition Planning. In developing plans, drawings, work statements, specifications, or other product descriptions, agencies shall consider, as appropriate, a broad range of factors including: elimination of virgin material requirements; use of biobased products; use of recovered materials; reuse of product; life cycle cost; recyclability; use of environmentally preferable products; waste prevention (including toxicity reduction or elimination); and ultimate disposal. These factors should be considered in acquisition planning for all procurement and in the evaluation and award of contracts, as appropriate. Program and acquisition managers should take an active role in these activities.

[12] Executive Order 13123 - Section 101. Federal Leadership. The Federal Government, as the Nation's largest energy consumer, shall significantly improve its energy management in order to save taxpayer dollars and reduce emissions that contribute to air pollution and global climate change. With more than 500,000 buildings, the Federal Government can lead the Nation in energy efficient building design, construction, and operation. As a major consumer that spends $200 billion annually on products and services, the Federal Government can promote energy efficiency, water conservation, and the use of renewable energy products, and help foster markets for emerging technologies. In encouraging effective energy management in the Federal Government, this order builds on work begun under EPACT and previous Executive orders.

[13] First announced at the U.S. Green Building Council annual meeting, Washington D.C., April, 2000

Green Building Guidelines & Rating Systems

One of the most challenging issues in the development of green building guidelines is that what constitutes 'excellence' or 'best practices' in building performance is unknown, since such definitions are still in development. Environmental goals are generally complex and often conflicting. Many times local, regional and global objectives are incompatible. And even within a particular climate region, different building types have different needs and therefore, different environmental priorities may apply. This chapter is an introduction to the guidelines that are available now, or soon will be. In some cases the guidelines are merely 'checklists', which lead to a final review of the design's 'greenness'. Other documents reflect an effort to set out a more comprehensive guide, considering every implication in coherence with an integrated approach to building design. Another type of document is the environmental performance assessment tool, which usually includes an extensive description and table in which each sustainability sub-goal is connected with a related building code, and with applicable technologies or strategies, while making a distinction between 'standard practice', 'advanced' and 'innovative' solutions.

Although they are all inherently different, most guidelines include similar issues:

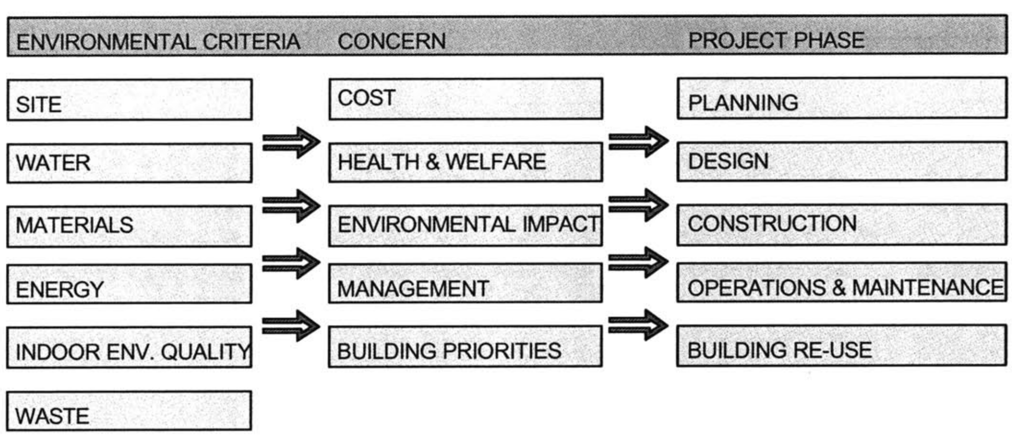

Figure 2.1 - Guidelines Issues

City Governments

Local city governments often own and operate their own buildings. As with the federal government, many cities or other local governments have adopted a sustainabilty directive for their own projects. They also have many administrative, policy, financial and regulatory tools at their disposal. Since they have jurisdiction, they can encourage and/or mandate green building construction practices.

There are three main types of city-sponsored building guidelines. (Fig. 2.2) One type is mainly for residential design. The first such document was written in 1993 by the city of Austin, Texas.[1] Since then many cities have made available similar guidelines. These are voluntary city-wide initiatives, co-sponsored by the National Home Builders Association (NHBA). The guidelines provide a template for developing a green builder program, and include many pre-design issues such as determining projected interest and budgeting. A second type, which is designed for non-residential projects, is targeted for use by all builders, designers and owners. These are usually written for voluntary use, and are more of a general guide of strategies. The third type is an in-house document written specifically for use by city building departments and their consultants. These are usually more prescriptive based, and designed for mandated use on all city owned projects.

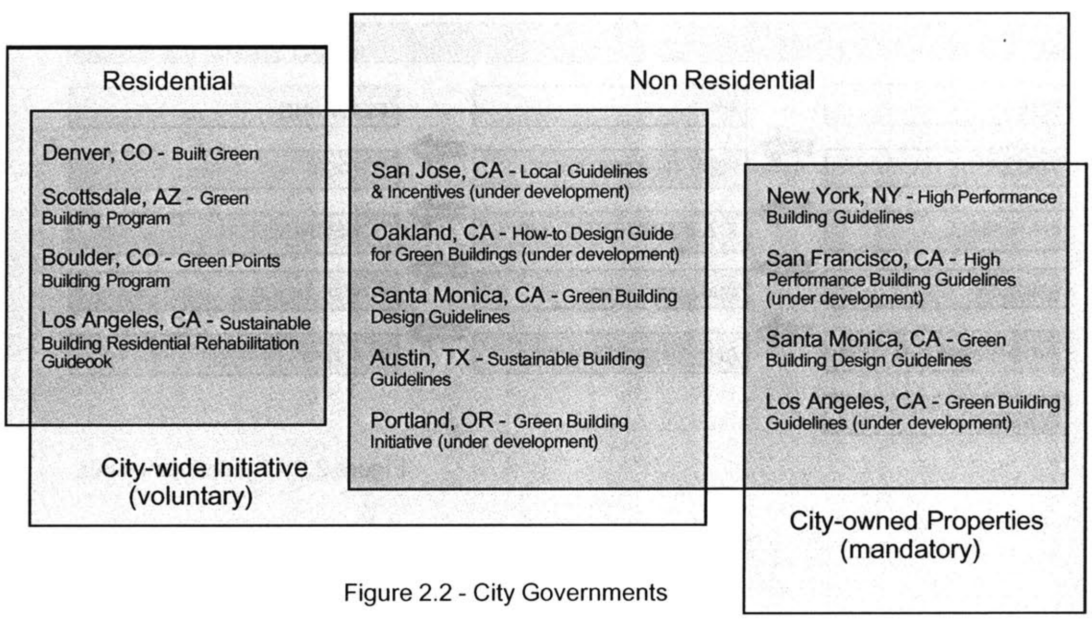

Figure 2.2 - City Governments

State and County Governments

State and county guidelines fall into three main categories. (Fig. 2.3) Again, NHBA sponsored, where the organization provides a 'green builder program' template for the county to follow. These are voluntary, but have many benefits, including the possibility of lower mortgage rates in some cases. They are developed as a checklist covering the standard environmental issues, i.e. site, water, materials, energy, ieq, waste, etc. The second type of guidelines focus on non-residential projects and have examples in both voluntary statewide initiatives, and state-owned facilities. These have been drafted with a particular purpose and building type in mind. Of these, Minnesota's *Sustainable Design Guide and Rating System* has a scoring system that allows the design team to prioritize environmental criteria, and to evaluate the building's performance. In addition, it contains a project history guide, so that the lessons learned on one project can be applied to another similar project. These two features make this guide unique. Pennsylvania's *Guidelines for Creating High Performance Green Buildings* is an especially good reference because it incorporates green concepts into the different project phases of design and construction.

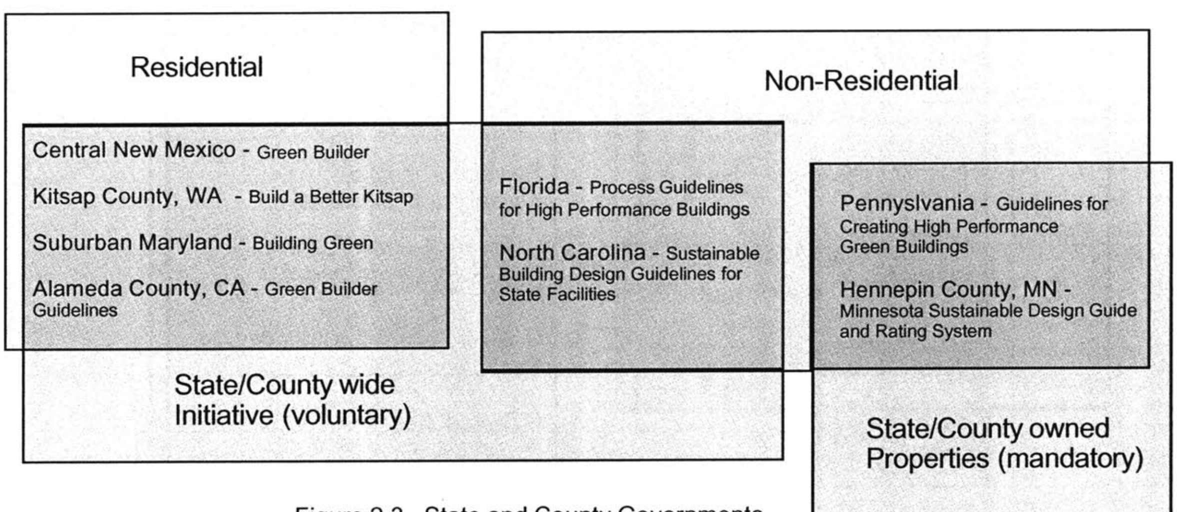

Figure 2.3 - State and County Governments

In-House Reference Guides

All of these documents have been written with a particular project, building type, organization or firm in mind. They were either written internally, or by a contracted consultant firm specifically for their own intentions. The Navy's *Whole Building Design Guide* is organized by design criteria: sustainable, secure, durable, cost-effective, productive, aesthetic; building types; and the typical Construction Specifications Institute (CSI) divisions 1 through 16. Its purpose is to "provide an overview of the various concepts and best practices associated with good building design."[2] It is unique in that it is an internet-based guide that provides links to standards and criteria, commercially available green products, technology resource pages and software-based design tools. HOK's *Sustainable Building Handbook* and the Air Force's *Environmentally Responsible Facilities Guide* both focus on the process of design, while the USPS's *Building Design Standards* and the U.S. Park Service's *Guiding Principles of Sustainable Design* suggest specific actions to be taken. The *Greening of the White House and Pentagon*, Battery City Park's *Residential Environmental Guidelines* and the USPS were written with specific buildings or projects in mind.

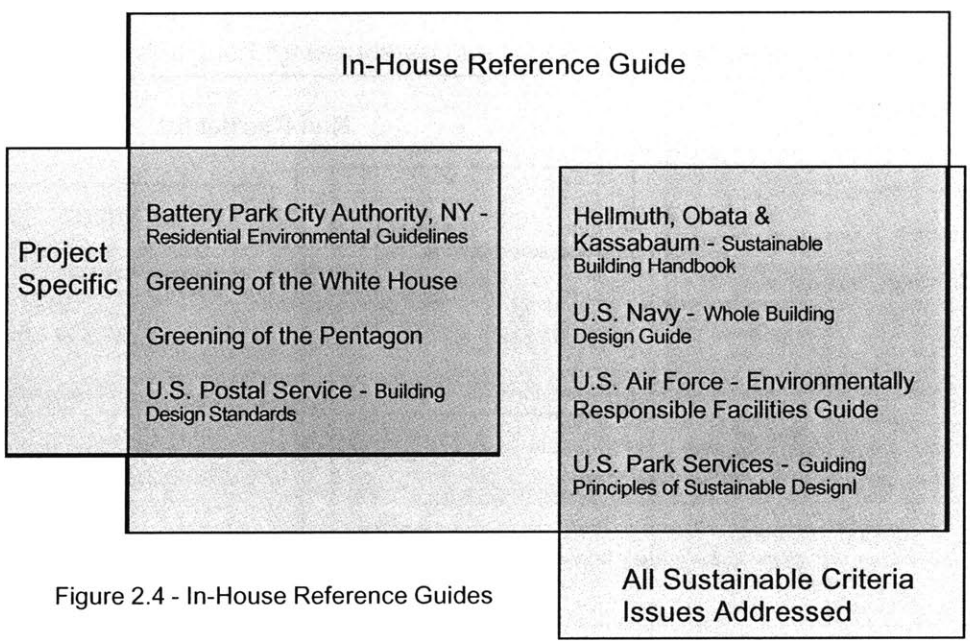

Figure 2.4 - In-House Reference Guides

Universities

There are many universities across the country that have made a commitment to integrating environmentally responsible development practices into its construction programs. These practices usually have adopted a policy that addresses resource conservation, waste reduction strategies, disposal of toxic materials and emissions, recycling and the use of recycled materials. Sustainable development concepts, applied to the design, construction, operation, renovation, and demolition of buildings and landscapes are consistent with overall campus-wide environmental initiatives. The following campus' all have projects in development, and have taken different approaches. The three main categories are campus initiatives, process oriented, and building guidelines. Many schools have chosen to adopt the LEED standard as a base reference. While it is certainly facile to use a LEED rating, it may not be the best answer for every university. Adopting LEED as a standard provides the recognition of an established rating for new buildings, and offers the design team a built-in support system for understanding green strategies. It also allows the consultants a pre-defined guideline document to follow. But the LEED system was written as a nation-wide standard, therefore it is not region, or building specific. A possible solution would be to tailor the LEED guideline to incorporate the specifics of the university. This would be used as an addition to the LEED requirements.

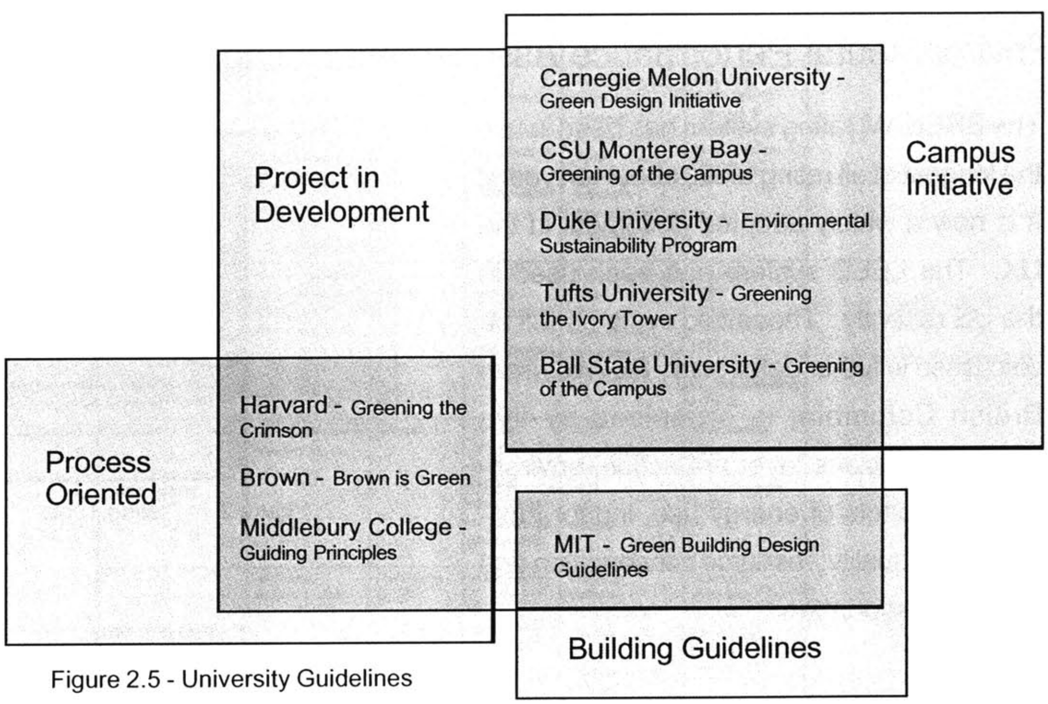

Figure 2.5 - University Guidelines

Resource Guides

Resource guides compile the vast amount of information available and make it easier to use. They generally include detailed information about materials and product listings. Some provide case studies. The *Sustainable Building Technical Manual* is organized by project phase, with each chapter authored by a different expert. It is a good general reference guide and provides information for writing building guidelines. The AIA's *Environmental Resources Guide* provides in depth information on the environmental impacts of building materials and offer guidelines for comparing systems such as light framing, insulation, cladding, wall finishes, resilient flooring, architectural coatings, glazing and carpeting.

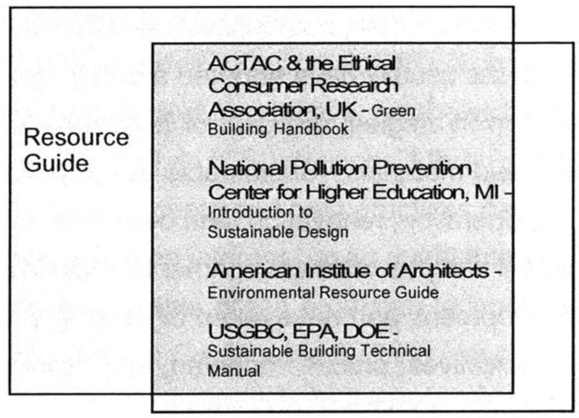

Figure 2.6 - Resource Guides

Environmental Performance Assessment Rating Tools

The BREEAM rating system has been in use the longest of all rating tools, about ten years. It is now a widely adopted document in the UK. The LEED system has been used in the US recently. These two systems will be discussed in futher detail later. BEPAC, from British Columbia, is organized by five catagories: ozone layer protection, environmental impacts of energy use, indoor environmental quality, resource conservation and site & transportation.

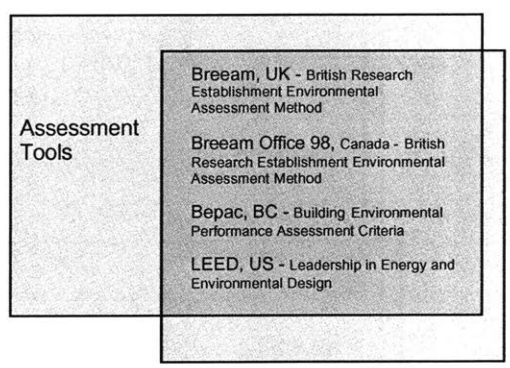

Figure 2.7 - Rating Tools

Five Comparisons

The following 5 guidelines have been chosen because they are all valuable references in different ways. The *Leadership in Energy and Environmental Design* (LEED 2.0) is the emerging industry standard in the United States. *British Research Environmental Establishment Method* (BREEAM) is one of the first established, and among the more widely used environmental performance assessment tools. Pennsylvania's *Guidelines for Creating High-Perfomance Green Buildings* is a good reference for the process of creating guidelines and integrating the guidelines into the different phases of building. Hellmuth, Obata & Kassabaum's (HOK) *Sustainable Design Guide* is written from the design team's perspective, and comes from a firm that has been instrumental in drafting several other guidelines. British Columbia University's *Facilities Branch Environmental Guidelines,* was chosen because it is an example of a university developed tool.

Figure 2.8 - Comparison of Five Guidelines and Rating Tools

Name & Date of Publication	Users	Type of Guide	Project Types	Design Categories	Project Phase
LEED 1.0, 1998 **LEED 2.0, 2000**	•Architects •Owners •Developers	Self-assessed rating system	•New Construction •Renovation •Institutions •Healthcare •High-rise Residential •Commercial real estate	•Site •Water •Energy •Materials •IEQ •Innovation	•Schematic •Design development •CD's •Construction •Commissioning •Application
BREEAM, 1990	•Architects •Tenants •Bldg managers •Owners •Government agencies	Third party assessed rating system	•Office •Superstores •Industrial •Residential •Existing •Renovation	•Management •Health •Energy/CO2 •Transportation •Water •Materials •Land use •Site ecology •Pollution	•Building performance • Design & procurement •Management & operations
Pennsylvania, 1999	•State agencies •Architects •Decision makers	Reference Guide	•Office •Public •Institutional •Residence •Laboratory	•Team building •Site •Enclosure •Mechanical •Interiors •Materials	•Design & const. •Design optimization •CD's •Bidding •Commissioning •O & M
HOK, 1998	•Architects •Project teams	Checklist	•Master plans •Office •Retail •Historical •Constructed wetlands	•Site •Energy •Materials •IAQ •Water •Waste	•Predesign •Design •CD's •Construction admin.
BC University, 1995	•In house design teams	Reference Guide	•University	•Natural systems •Energy use •Health & well-being •Integration of principles	•Campus planning •O & M •Integrated design approaches

LEED

The US Green Building Council (USGBC) began to develop the LEED rating system in 1995 in response to the market's demand for a definition of 'green building'. Other rating systems such as BEPAC and BREEAM existed at that time, but there was no such system in the US. USGBC is a national, non-profit organization with over 500 members nation-wide.[3] Its purpose is to accelerate the implementation of green building policies, programs, technologies, standards and design practices. LEED has been adopted and mandated by many US governmental agencies for their own building design, which will inevitably encourage the market transformation of supporting green technologies. It encourages and guides a collaborative, integrated design team and construction process. It is a self-rating tool that results in one of 4 ratings. The rating process can be lengthy and expensive depending upon the project type and experience of the consultants. There are four levels of certification depending on the number of points awarded:

- LEED Certified 26 - 31 points
- Silver Level 32 - 37 points
- Gold Level 38 - 44 points
- Platinum Level 45 + points

Criteria	Required Credits	Total Points Available	Weighting % of Total
Energy & Atmosphere	3	17	25
Indoor Environmental Quality (IEQ)	2	15	22
Sustainable Sites	1	14	20
Materials & Resources	1	13	19
Water Efficiency		5	7
Innovation & Design Process		5	7
Total	7	69	100

Figure 2.9 - LEED Criteria Weighting

In addition to the basic credits of site, water, energy, materials, and indoor environmental quality (Fig. 2.9), there are four innovation credits that LEED does not specifically address, which can be applied for with innovative green building design or construction practices.

These innovation credits are a major difference between LEED 1.0 and 2.0. LEED 2.0 allows for flexibility that is not specifically defined in the document. Other changes in version 2.0 include a move to performance-based, rather than a prescriptive-based, requirements.

Fig. 2.10 is an example of one of the available credits in the site category. Each credit identifies the intent of a project, and describes the overall requirements for achieving the available points, usually citing an existing building code that is either performance or prescriptive based. It then cites technologies and strategies, and provides suggestions for achieving the stated requirements.

Site Credit 2: Urban Redevelopment Points: 1	**INTENT:** Channel development to urban areas with existing infrastructure, protecting greenfields and preserving habitat and natural resources.
	REQUIREMENT: Increase localized density to conform to existing or desired density goals by utilizing sites that are located within an existing minimum development density of 60,000 square feet per acre (2 story downtown development).
	TECHNOLOGIES/STRATEGIES: During the site selection process give preference to previously developed sites with urban redevelopment potential.

Figure 2.10 - Example LEED Criteria

A drawback of any rating system is the problem of prioritization. Inherent in these systems are value judgements on what constitutes a 'green building'. Because LEED is a national standard, it could not possibly regionalize the criteria, or give priority weighting to the specific climate zones. Establishing different LEED tools for different building types has been discussed, such as retail and residential. This would at least address the issue of different building uses. Another criticism is that these systems can be very 'heavy' in one criteria area, while virtually ignoring others. Although there are minimum pre-requisites that must be adhered to, this can lead to a potential non-holistic building by allowing buildings to meet the threshold by capturing points in only a few areas. The value rests in the requirements needed to achieve the credits.

The backbone of LEED is the referencing of existing building codes and standards across the country. (Fig. 2.11) The intent was not to duplicate work already done, but rather to bring buildings across the nation to a higher than minimum standard. The criticism here has been that there should be an even higher standard. But again, the intent of this document at this time, is to transform the market and kick-start the supporting green technologies. To achieve the higher ratings, such as silver and platinum, these standards must be bested by a large marginal percentage.

Maryland Model Erosion and Sediment Control, Sections 4.2 (e) and (f)
EPA/ DOE EnergyStar® Benchmarking Tool
ASHRAE Standard 62- 1989 (IAQ)
ASHRAE Standard 55- 1992 (Thermal Comfort)
ASHRAE/IES 90.1-1989 (Energy Efficiency)
South Coast Air Quality Mgmt. District 1168 (Low VOC)
Energy Policy Act of 1992 (Plumbing Fixture)
California State Title 24 (Lighting Requirements)
SCAQMD Southcoast Rule #1168 (Building Materials)
DOE Building Measurement and Verification Protocol
US GSA Model Commissioning Plan and Guide Specification

Figure 2.11 - LEED Standards and Building Codes

BREEAM

The Building Research Establishment Environmental Assessment Method, or BREEAM, was first developed in 1990 by the BRE, ECD Energy and Environment, Ltd.,[4] in the UK. BREEAM was conceived as a marketing and auditing tool, rather than a design tool, which assesses a buildings' environmental quality and performance in terms of environmental impact, energy efficiency, health, operations and management. BREEAM is a tool that allows the owners, users and designers of buildings to review and improve environmental performance throughout the life of a building. BREEAM works by awarding 'credits' for meeting different environmental targets. These are summarized on a certificate, which the client displays in the building or uses in publicity material. For some building types, a summary of performance is expressed as a single rating of Fair, which is greater or equal to 60% of the total points available, Good – 70%, Very Good – 80%, or Excellent – 90%, based on the distribution of credits. BREEAM offers its users pre-assessment design support from authorized assessors, and independent monitoring and advice during the design process. It provides an opportunity to demonstrate and benchmark environmental performance recognition with a market label, indicating that a building has achieved a certain level of environmental performance. The methodology is based on a questionnaire, as well as an on-site visit of the building that includes assessment of the mechanical room, common areas and typical tenant areas. It also includes a meeting with the building's management. Measurements are made, including carbon dioxide, lighting and sound levels, and others. Because this is a certification program, all the supporting documents needed are verified.

The assessment is reported in two stages. The preliminary report indicates how the building performed and recommends realistic measures to improve the rating. The final report takes into account any of the subsequent improvements. A certificate accompanies the final report and provides third party endorsement of the building. Credits are awarded in three sections: global issues and use of resources, local issues and indoor issues. Again, a criticism is that there is not a user-defined ability to prioritize the criteria. Looking at the weighting of the criteria, (Fig. 2.12) it is noted that BREEAM rates the use of timber as the primary criterion for a green building. CO2 production and CFC/HCFC emissions is the secondary priority, and the ecological value of the site is the third priority. The use of hazardous materials, and recycled & renewable resources, as well as the storage of these items, rate fourth in their value of criteria.

Criteria	Required Credits	Total Credits Available	Weighting % of Total
Global Issues and Use of Resources:			
Carbon Dioxide Production Due to Energy Consumption	1	1	10.5
Low-Energy Lighting		1	2
Gas Cooking		1	2
CFC and HCFC Emissions	1	1	10.5
Timber	2		16
Renewabel, Non-Renewable and Recycled Resources		4	8
Storage of Recyclable Materials	1		8.5
Local Issues:			
Ecological Value of the Site		3	10
Water Economy		2	6
Indoor Issues:			
Hazardous Materials	1		8.5
Daylighting		1	6
Thermal Insulation Materials in Lofts		1	6
House Log		1	6
Total	**6**	**16**	**100**

Figure 2.12 - BREEAM Criteria Weighting

Pennsylvania

Pennsylvania's *High-Performance's Green Building Guidelines* is mainly intended to familiarize decision-makers with the concepts of sustainability. It is formatted to incorporate theory, practice, concepts, case studies and checklists to present the subject without dictating solutions. It is not meant to be a prescriptive document. The document's value is in the directive for the process of drafting and integrating green building design guides. It specifically states all of the steps necessary to overcome stakeholders' hesitancies and accomplish the goal of a workable document. The process, as it is described involves the following steps:[5]

Team building and goal setting, which includes developing a vision statement, and goals that reflect the vision, defining achievable design criteria, and prioritizing the criteria.

Design optimization, which looks at the systems and products as the building is being designed to ensure the intended goals are reached and exceeded. One of the purposes of design optimization is to scrutinize the large, overarching goals set at the beginning of the project to see if the effort is on track. Another is to take advantage of each additional opportunity as the project evolves.

Development of construction documents and specifications, which includes formulating a statement of intent and creating a performance program to document the overall strategy for integrating the parameters of the project and specifications by CSI division. The statement of intent includes a description of how systems are to perform. The creation of a performance program to document the overall strategy for integrating the parameters of the project must consider: budgets, site utilization, space planning, integrated building systems, and occupancy issues, and set target limits.

The bidding & construction phase, which includes an ongoing budget and cost feedback system. Advantages of the team approach include having the opportunities for ongoing budget and cost feedback, and for investigating project options as they occur. It reduces cost-increased bids due to 'specialized' methods and materials. It controls principles during construction by anticipating the pressure of contractors and sub-contractors who might want to substitute green materials and practices with those that are familiar to the general and sub-contractors.

Building commissioning, which is the post-construction process of ensuring that building systems are designed, installed, functionally tested and capable of being operated and maintained according to the owner's operational needs. Systems that require commissioning include mechanical: hot water heating, pumps, cooling tower, air handling equipment and controls; plumbing: service water heaters, pumps, tanks, compressors, controls; electrical: security systems, emergency generator systems, fire management systems, controls; and other: sprinklers, elevators, audio/visual systems, controls.

Operations & maintenence phase, which includes: educating all building occupants and other appropriate parties about the goals and benefits of the O & M program. The return on investment can only be realized if the design and construction process includes an integrated approach to operation and maintenance.

Hellmuth, Obata & Kassabaum (HOK)

HOK's *Sustainable Design Guide* is an example of a document written by an in-house team that based their recommendations upon their own experiences implementing sustainable design strategies on various projects. It is a good reference for the basic steps. Their current document, *The HOK Guidebook to Sustainable Design*, includes a large case-study section. HOK state that the current design process is largely linear, which is a recognized problem. According to HOK, sustainable design involves 6 key steps in the revised facility delivery process.[6]

Team formation. From the beginning of the project, their advice is to include, in addition to the design team, the engineers, contractors, major sub-contractors, operations management, various consultants, and in some cases, the key suppliers. (However, they neglect to list the users of the building.)

Project initiation, which has two stages: education and goal setting. The whole team must be educated concerning basic environmental problems and opportunities, and then environmental goals for the project must be set.

Optimization, which is the process of questioning each component and process to achieve the best results with the least expenditure of resources. They compare this to the budget process in that all decisions are reviewed through a 'green' filter.

The project actions, which, in the HOK guide, refer to the construction documents and specifications phases.

Bidding and construction. This process can sometimes be complicated because of the many players involved at this time. According to HOK, there should be educational sessions on environmental goals, just as there are sessions for new workers concerning job site procedures and safety.

Post occupancy. As with the other guidelines, attention to operations and maintenance is imperative for sustainable buildings.

The sustainability checklist includes key sustainable design objectives for the three major project phases, which have been defined as: pre-design, design & documentation, and construction administration. Each phase is further divided into six areas of sustainable design: planning, energy, building materials, indoor air quality, water conservation, and recycling and waste management. Table 2.13 is an example of one of their project actions for the site category. The project actions are recommendations by phase and topic that should be considered during the design process. In this case the phase is pre-design and the topic is general. Goals are included to provide additional guidance to the design team and to assist in measuring performance similar to that of LEED's requirements. For easy reference while using this document, the letters P, for programmer, and LA, for landscape architect, are used to denote the design members involved at that phase. Further references indicate the potential effect on the owner, time or expense. For example, the letter O, requires consultation with the owner, $F – affects the fees, and $C – affects the construction costs.

Figure 2.13 - HOK Project Action Example

Project Actions - Site	
Pre-Design - General	
P, LA O, $F	1. Suggest that an expert on sustainable landscape planning and design be included as an integral member of the design team
P, LA O, $C	2. Check local and state legal requirements for erosion control. Consider the adoption of more stringent requirements if necessary to protect the site and surrounding areas
	Goal: Comply with sections 4.2 e. & f. of the Maryland Model Erosion and Sediment Control Ordinance and Section 6 (group 2) of the Maryland Model Stormwater Management Ordinance

British Columbia Universtiy

These guidelines are primarily directed at teams engaged in designing new facilities for universities and colleges in British Columbia. They both reflect and communicate an expectation that all new building projects and major renovations will be designed to their self defined high environmental standards. The first section involves the integration of principles. It is their contention that educational institutions should strive to effect a comprehensive, holistic and environmentally sustainable approach to development and operation by consideration of all of the following issues:[7]

Changing context: identifying the environmental design goals and directives.

Respect for Natural Systems: being conscious of, and responsive to, the ecology of the site and of existing natural systems.

Energy efficiency: emphasizing the importance of energy in sustainable building strategies and identifying architectural and engineering design strategies to reduce building operating energy use.

Resource Use: engaging in more effective and efficient use of resources in the construction, maintenance and operation of buildings than is currently practiced through use of a more detailed definition of sustainability.

Health and Well-Being of Users: considering design strategies which enhance thermal quality, indoor air quality, lighting and acoustic quality.

A final section which identifies key inter-relationships between the various environmental issues and design strategies covered in the previous sections.

The following provides an overview of the sustainability issues, which are being cited as part of a new agenda for building design and operation. These issues include:

Environmental guidelines - According to BCU, sustainability requires first and foremost an attitudinal shift, to embrace new ways of thinking about the processes of production, use and disposal of buildings.

Performance goals - Environmental performance goal setting must, however, take place in conjunction with commitments to economic considerations, public acceptability, and technological and administrative feasibility.

Comprehensive evaluations of design alternatives - Designing post-secondary education facilities to higher environmental standards has both capital and operating cost implications and also has maintenance implications that must be considered in design alternatives.

Broader environmental commitment - Wherever possible, building design should make environmental strategies explicit so as to communicate an emerging emphasis for these broader environmental considerations

Issues covered in guidelines - Changing context in universities, including both management and site related issues:

Section 1 – Introduction

Section 2 – Project planning and management

Section 3 – Energy efficiency

Section 4 – Resource conservation

Section 5 – Health & well-being of users

Section 6 – Integration of systems

SUMMARY: ENERGY GOALS & STRATEGIES				
Energy Issue	**Section**	**Applicable Standards**	**Advanced**	**Innovative**
ENERGY GOALS	3.0.2	ASHRAE/IES Std. 90.1-1989	75% of ASHRAE/IES Std. 90.1	50% of ASHRAE/IES Std. 90.1
SITING AND SITE PLANNING	3.1		Landscaping strategy integral part of energy strategy; planting to minimise north exposure; examination of impact on daylight potential. Careful selection and placement of deciduous vegetation on south orientations; reflective ground cover to enhance daylighting in lower buildings.	Maximum use of ambient energy sources offered by the site.
BUILDING MASSING & ORIENTATION	3.2		Building form evaluated comprehensively taking into account building heat loss, solar gain and daylighting	

Figure 2.14 - British Columbia University Summary Example

Conclusions

While all of these guidelines and assessment tools differ, they all greatly emphasize that sustainability, or green building design is more than just energy efficiency. It is a holistic approach to planning, design, construction, operations & maintenance, and building reuse. They redefine buildings in terms of quality of performance, rather than aesthetics alone. Green building guidelines and rating systems demystify what green buildings are, and define what constitutes a green building by identifying qualitative and quantitative measurements of improvement.

Notes

[1] The City of Austin implemented Green Building into their own facilities in 1993. In 1994 a resolution form City Council directed the creation of Municipal Guidelines. http://www.ci.austin.tx.us/greenbuilder/programs.htm

[2] Communication Magazine, Summer 98, *Navy takes on a "Whole Building Design" approach,* p25

[3] United States Green Building Council, http://www.usgbc.org/

[4] British Reserach Establishment, http://www.bre.co.uk/sustainable/service1.html

[5] Kobet, Bob & Wendy Powers, Conservation Consultants, Inc., *Guidelines for Creating High-Performance Green Buildings*, Pennyslvania Department of Environmental Protection, 1999

[6] Mendler, Sandra, AIA, *Sustainable Design Guide,* Hellmuth, Obata + Kassabaum, January 1998, p.iv-vi

[7] Government of British Columbia, Public Post Secondary Institutions, *Environmental Report, Section 1.6,* http://www.aett.gov.bc.ca/environmental/data/environt/sec-one.htm#1.4

Sustainability Tools

In order to develop a better understanding of the building design performance, the operation of the structure needs to be estimated. There are many different building operations to be concerned with: thermal performance, energy efficiency, ventilation, heat flow through construction details and lighting quality. To achieve the most sustainable plans, architects require effective tools for analyzing and understanding the complex behavior of the building in terms of its environmental impact and indoor environmental quality. To that end, there has been the development of many computer-based design and simulation tools. The targets of simulation analysis include providing comfortable indoor environmental conditions at an acceptable fuel consumption level, and optimizing systems performance. Sith sustainability tools, complicated design problems can be investigated and their performance can be quantified and evaluated.

The tools available to architects and engineers concerned with building performance are computer-based building simulation, life cycle analysis and design tools. They range from the simple and approximate to the detailed and sophisticated. Most of the research relates to studies of fundamental theory and algorithms of load calculation, which results in some simplified methods, e.g., degree-day method, equivalent full load hour method, and bin methods, to predict the energy consumption of buildings, and some detail methods like weighting factors to predict peak cooling load. Selection of a sustainability program should consider the project requirements, time and cost to perform the simulation, availability and capacity of the computer system and the experience of the user.

Although there are many advanced tools available, they remain largely unused by most architects. In order to analyze and simulate building behaviors, large amounts of detailed information regarding the location, size, configuration, and context of the building design is required that is usually input via the keyboard. The outputs are usually in the form of tables and graphs that are difficult to interpret. As a result, many of these tools require a specialty consultant to prepare and are very costly. Or conversely, the programs are too rudimentary and therefore are limited in usable information. Another barrier to using these tools is that the multiple concerns require different sets of data to be input in different formats, so that each one requires a different program. Again, this is time consuming and costly to prepare and review.

Popular applications include:

Simulation Tools

Whole building energy performance analysis

Building energy simulation is performed to analyze the energy performance of a building dynamically and to understand the relationship between the design parameters and energy use characteristics of the building. Energy analysis can help to develop effective design strategies and would be used at the design development phase of the project. Simplified energy analysis programs, such as Energy-10 and Energy Scheming can be used at the schematic design.

Lighting and daylighting simulation

How the daylight is distributed over the space determines occupant satisfaction and the level of artificial lighting consumption. Optimization at this level supports decisions that aim to achieve a healthy environment with minimal electrical costs for the lighting. These tools would be used at the design development phase by the architect or engineer.

Computational fluid dynamics (CFD)

CFD is widely used in the study of global warming, urban climate, microclimate, building ventilation, indoor air quality, indoor thermal comfort, fire safety, and smoke extraction. At this time, most CFD programs are cumbersome and difficult to use.

Life Cycle Analysis Tools

Life Cycle Analysis (LCCA)

Life cycle analysis (LCA), is used for building materials and assemblies to compare design options based on life cycle costs. This method can be used at all phases of building by the architect, materials specifications writer, and contractor.

Life Cycle Cost Analysis (LCCA)

These programs are best used throughout the design process, so that decisions can be made based on up-to-date cost information.

Simplified Design Tools

Design tools are useful in the early design stages because they require simpler and less input data. The simulations are quick to run, so they can be used easily. Most of these tools are over-simplified, but are a good starting point when trying to understand the breadth of a sustainable project.

Simulation Tools

One of the most powerful techniques available to the designer is computer modeling and simulation. Modeling is defined as the art of developing a model that faithfully represents a complex system, and simulation is the process of using the model to analyze and predict the behavior of the real system.[1] The major consumers of energy in a building are the lighting, heating, ventilation and air conditioning (HVAC) systems. Therefore it is essential that thermal performance of buildings and mechanical systems are understood and optimized.

Effective application of building simulation requires a skilled user that can choose a suitable simulation program, and is knowledgeable in the input as well as interpreting the results. The goal of design in architecture is to achieve the best balance of performances in a complete set of application criteria. The architect designs in an iterative creative process and a full range of architectural issues and criteria have to be considered simultaneously. Understanding the design and performance relationship is essential and can be facilitated through building simulation.

Seven major steps have been recommended as a framework for a successful analysis:[2]

1. Defining the problem
2. Specifying the model
3. Data acquisition
4. Implementation
5. Planning
6. Experimentation
7. Analysis of results and reporting

Figure 3.1 shows the possible applications of energy analysis at various stages of the building design process. At the early design stages, only conceptual sketches and schematics, often rough and incomplete, are available. As the design proceeds, more information and detail will be developed. If energy analysis starts early in the generative design phase, then energy considerations can be integrated into the building form and design concept. It is believed that the best opportunities for improving the energy performance of a building occur early in the design process.[3]

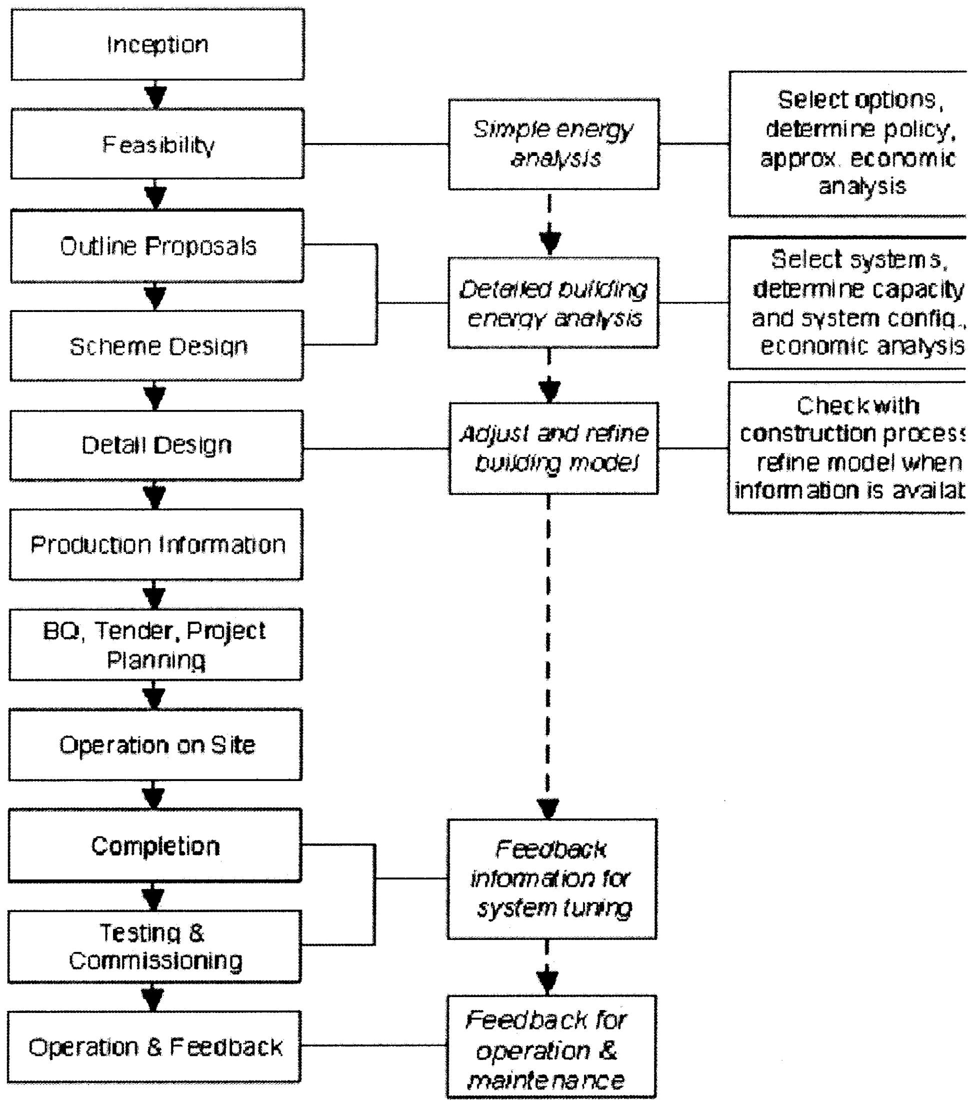

Fig. 3.1 Energy Analysis in the Building Design Process, source: Sam C M Hui, The University of Hong Kong, www://arch.hku.hk/~cmhui

The following is a discussion of several sustainability tools. For a complete list, see Appendix E.

POWERDOE

PowerDOE is the newest building energy simulation tool from the DOE family, from the Department of Energy. It is easier to use than the original DOE-2, due to the flexible Windows graphical user interface. PowerDOE's development began in 1992 as a collaborative effort of Lawrence Berkeley National Laboratory and the Electric Power Research Institute.[4] It is designed to serve a wide range of users, including building performance analysts, HVAC designers, architects, and electric and gas utility personnel and contractors.

PowerDOE has a modular structure that allows sections of the program to be accessed externally or connected with other analysis tools. For example, its Review Results module can be used as a stand-alone application for post-processing DOE-2 results. The PowerDOE structure allows third party developers to use these modules. It will also be linked to the Building Design Advisor, a multimedia-based, integrated building design support tool being developed separately at LBNL.

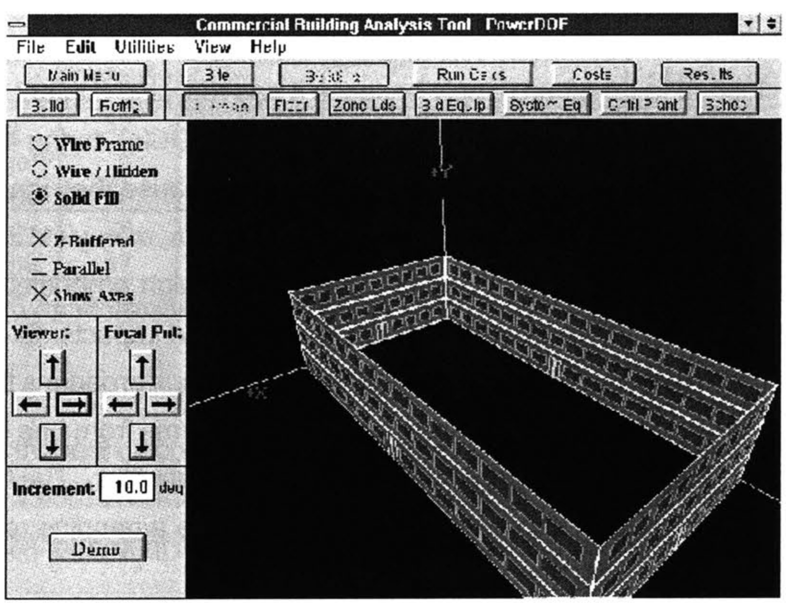

Figure 3.2 PowerDOE Schematic Design Tool, source CBS Newsletter Summer 1994 p8

Radiance

Radiance was developed at the Lawrence Berkeley National Laboratory and is used to study lighting and daylighting strategies, exterior horizontal light shelves, interior shading devices, interior layouts and material color selection. The user builds a model of the interior spaces and inputs each surface's shape, texture, size, location and composition. The program analyzes the lighting conditions for a specific date, time and type of sky condition.

Life-cycle Analysis of Building Materials

While design tools aid architects in basic decisions such as building siting and massing, and energy simulation tools provide information regarding predicted performance, life-cycle analysis (LCA) tools attempt to quantify the economic, social and environmental components of sustainability as the basis for comparing building products and designs. LCA is a way of examining the total environmental impact of a product through every step of its life—including raw materials extraction (for example, through mining or logging), and processing, product manufacture, transportation, installation, operation and maintenance, and ultimately recycling and waste management.

A product is claimed to be green simply because it has recycled content, or claimed not to be green because it emits volatile organic compounds (VOC's) during its installation and use. These single-attribute claims may be misleading because they ignore the possibility that other life-cycle stages, or other environmental impacts, may yield offsetting impacts. For example, the recycled-content product may have a high embodied energy content, leading to resource depletion, global warming, and acid rain impacts during the raw materials extraction and manufacturing life-cycle stages. LCA thus broadens the environmental discussion by accounting for shifts of environmental problems from one life-cycle stage to another, or one environmental medium (land, air water) to another. The benefit of the LCA approach is in implementing a trade-off analysis to achieve a genuine reduction in overall environmental impact, rather than a simple shift of impact.

There are four main life-cycle analysis tools: BEES from the US, Athena from Canada and Envest from the UK, and EcoQuantum from the Netherlands.

BEES – Building for Environmental and Economic Sustainability

Developed by the U.S. National Institute of Standards and Technology (NIST), BEES 2.0 help designers, builders and product manufacturers evaluate cost-effective green building products using the LCA approach. It includes comparative environmental and economic performance data for generic building products used for framing, wall finishes, wall and roof sheathing, insulation, roof and floor coverings, slabs, basement wells, beams, columns, parking-lot paving, and driveways

First, one sets the analysis parameters. BEES uses preference weights for environmental versus economic performance. For example, if environmental performance is the only important consideration, a value of 100 is entered. Next you are asked to select your relative preference weights for the environmental impact categories, the following Table 3.1 shows the choices available

Weight Set:	Global Warming	Acidifcation	Eutrophication	Natural Resource Depletion	Indoor Air Quality	Solid Waste
User-defined	17	17	17	17	16	16
EPA Science Advisory Board	27	13	13	13	27	7
Harvard Study	28	17	18	15	12	10
Equal Weights	17	17	17	17	16	16

Table 3.3 Environmental Impact Category Weights, source: BEES Program

Finally, one enters the real discount rate for converting future building product costs to their equivalent present value. The maximum value allowed is 20%. The 2000 rate mandated by the U.S. Office of Management and Budget for most Federal projects, 4.2%, is provided as a default value.

The next step is to select the building element for comparison. BEES 2.0 allows comparison for 65 products across 15 building elements: slabs on grade, basement walls, beams, columns, roof sheathing, exterior wall finishes, wall insulation, wall sheathing, framing, roof coverings, ceiling insulation, interior wall finishes, floor coverings, parking lot paving, and driveways. And finally you must select the transportation distance form the manufacturing facility to the building in which the product will be installed.

The results are computed and displays the BEES environmental and economic performance scores. By default, three summary graphs are selected for display or printing: Overall Performance, Environmental Performance, and Economic Performance.

For example, a comparison of three roof coverings, asphalt shingles, clay tiles and fiber cement tiles can be compared on the basis of their life-cycle costs to determine which is the least cost means of covering the roof over the study period. For this example the discount rate is the default 4.2%, a 50% economic and 50% environmental weight and the EPA-based criteria weighting have been chosen as parameters.

Figure 3.4 shows the BEES Environmental Performance Results displaying the weighted environmental performance scores for our example. Lower values are better; if a product performs worse with respect tall environmental impacts, it receives the worst possible score of 100. The graph breaks down the weighted environmental score by its six contributing impact scores: Global Warming Potential, Acidification Potential, Eutrophication Potential, Natural Resource Depletion, Indoor Air Quality and Solid Waste. In this case, asphalt tiles are the better choice, although not shown are results for embodied energy, which names fiber cement tiles are the better choice. In sum, the answer depends on the tradeoffs.

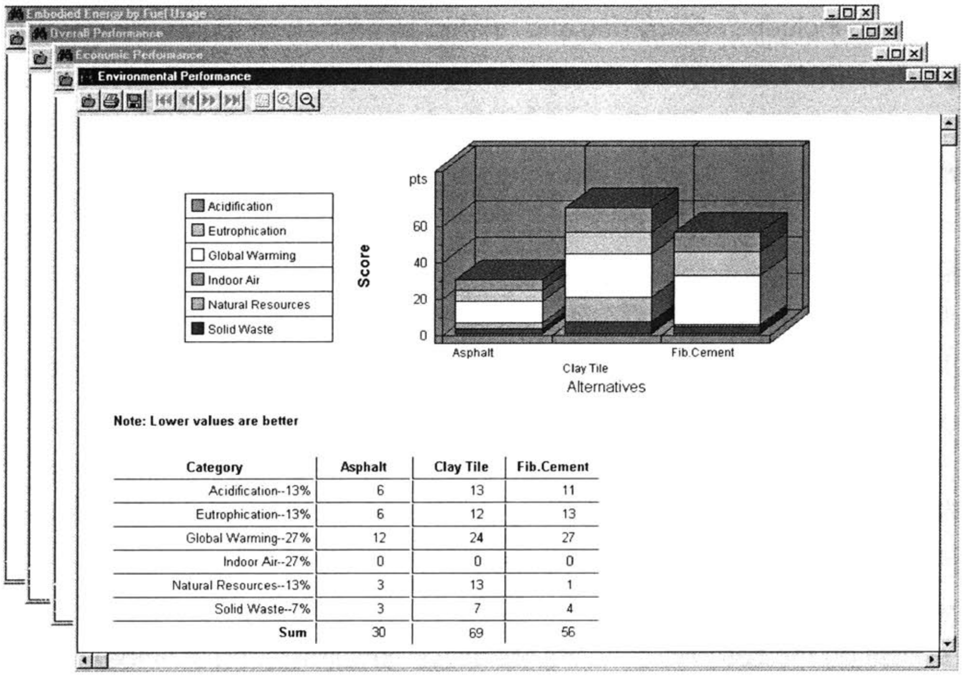

Figure 3.4 BEES Environmental Performance Results, source BEES Program

ATHENA

While BEES is a product comparison LCA tool, ATHENA compares building assembly options. The program includes low-rise commercial, institutional, light industrial and residential buildings.

The ultimate goal is to encourage selection of material mixes and other design options that will minimize a building s potential life cycle environmental impacts and foster sustainable development.[5]

An ATHENA user first enters a general description of a building project, including its location, and then specifies a design by selecting from typical assemblies or by entering specific quantities of individual products. The building location is identified as a region by selecting whichever of six cities in Canada best represents the region in which it is to be built.

The model also includes energy use and related air emissions for on-site construction of a building s structural assemblies. The inventory data includes natural resource, energy and water inputs to processes as well as emissions to air, water and land for the manufacture, transportation and use of all of the individual building products.

The following summary measures of potential environmental loading is provided:[7]

- ⊙ a global warming potential index, which aggregates atmospheric emissions that contribute to the greenhouse problem, developed using the CO2 equivalence method;
- ⊙ air and water pollution indices, developed using the critical volume method for the worst offender, to indicate the relative toxicity or health effects of groups of emissions to air and water and;
- ⊙ an index of the ecological carrying capacity effects of resource extraction (i.e. effects on the carrying capacity of ecosystems like those of timber harvesting on bio-diversity or the effects of mining on groundwater quality), developed from a survey of environmental and resource extraction experts and used in ATHENA to weight the absolute quantities of the main raw resource required to manufacture the products of interest.

The following Figure 3.5 shows global warming potential (greenhouse gas) results for a concrete vs. a steel office building. The results are broken down in the figure by activity state — resource extraction, manufacturing and on-site construction. These results are based on Canadian LCI inventory data for typical or average manufacturing technologies and practices, with the energy use and GWP results taking into account of transportation.

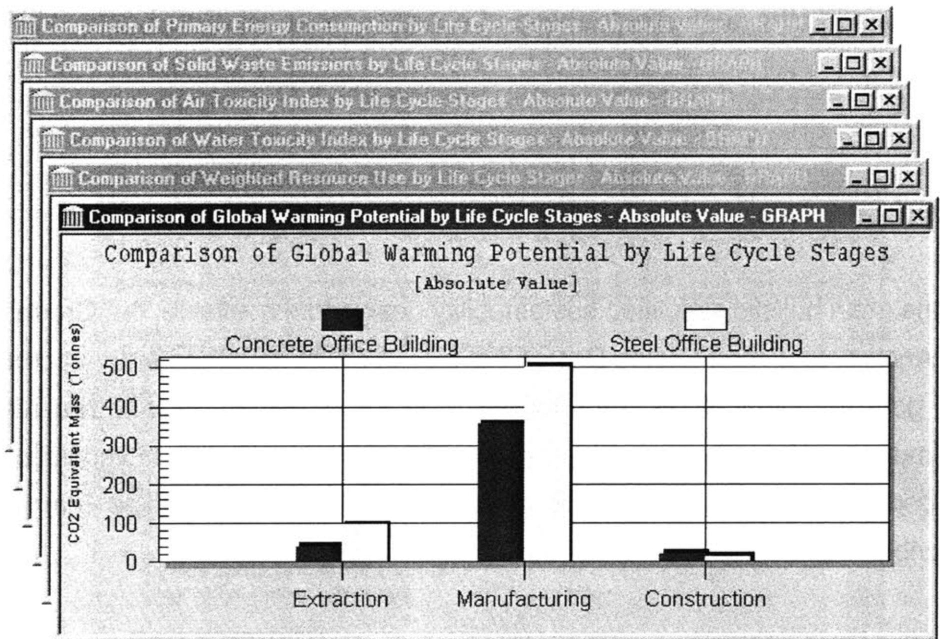

Figure 3.5 ATHENA Environmental Performance Results, source ATHENA program

Life-cycle Cost Analysis

TLCC = first costs plus all future costs (operating, maintenance, repair and replacement costs and functional-use costs) minus salvage value (i.e. value of an asset at the end of economic life or study period)

The NIST Building Life-Cycle Cost (BLCC) computer program provides economic analysis of proposed capital investments that are expected to reduce long-term operating costs of buildings or building systems. It is especially useful for evaluating the costs and benefits of energy conservation projects in buildings. Two or more competing designs can be evaluated to determine which has the lowest life-cycle cost. Or a project can be compared against a 'do-nothing' base case where no capital improvements are made to reduce further costs. In addition to comparing two or more alternatives, it computes the Net Savings, Savings-to-Investment Ration, Adjusted Internal Rate of Return, and Years to Payback. But these tools require specialized knowledge to use, both in the input and the interpretation of the results. Another good reference for LCCA is the National Bureau of Standards (NBS) Handbook 135, Life Cycle Costing Manual for the Federal Energy Management Program: a guide for evaluating the cost effectiveness of energy conservation and renewable energy projects.

Simplified Design Tools

There is one main holistic simplified sustainability design tool available, the Green Building Advisor.[8] Another tool, the Building Design Advisor[9] is still in development, but promises to be a very good tool that allows the user to model the project once, and receive project specific simulated information regarding energy efficiency, lighting, and ventilation. There are many computer based energy efficiency design tools available, such as Energy Scheming,[10] described below.

Green Building Advisor

This program is a very basic reference tool that gives the user a broad scope of issues to think about while designing. Because of the limited building description input data, the recommendations are not project specific. What makes this program unique is that it has a library of case studies, hot links to building project listings, technical articles and a bibliography. These features make this tool a good resource of information, rather than a project specific simulation tool. The most beneficial times to use this program are at the predesign and schmatic phases. A student, or designer would input information basic regarding the building description for new and renovation projects. The output is in a written format, and covers the following issues:

Site & ecosystem: site selection, land development, stormwater, landscaping, regional integration;

Energy use: building envelope, heating, cooling & ventilation, lighting, appliances & equipment, water heating, energy source;

Water use: landscaping, plumbing & fixtures, appliances, general;

Resources & Materials: resource efficiency, construction and demolition management, future waste minimization, materials by CSI division;

Indoor Environment

The Figure 3.5 below is an example of the information one would receive regarding the envelope under the energy category.

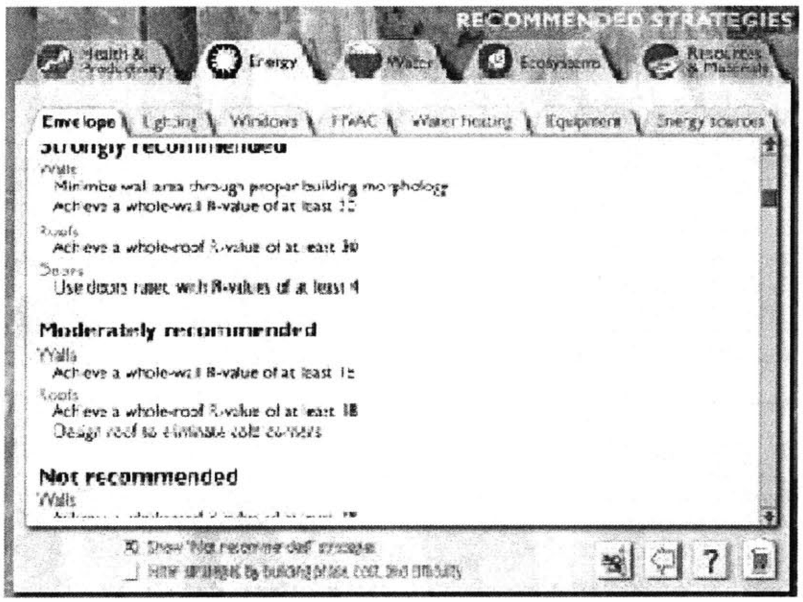

Figure 3.5 Envelope Strategies for Green Building Advisor, source GBA

Building Design Advisor 3.0

The greatest value in this tool is that it is linked to the established simulation tools DOE-2 for thermal and energy costs. It has an internal daylighting and electrical lighting component. Future versions will link to COMIS for airflow and indoor air quality, Radiance for daylighting, Athena for life-cycle analysis, a building rating system, cost-estimator, CAD software and product catalogues. The user then only has to model the project once, or even better, just input the CAD file already modeled for the construction documents, and will be able to receive the building simulations from each of these tools in return. While this program has a lot of promise, it is still is in the development stage and has many bugs. It is cumbersome to input and the modeling capacity is limited to rectilinear spaces in order to use the lighting simulation tools. This tool is best used at the schematic phase by a designer or architect.

The building information is modeled using the tools schematic graphics editor and includes information regarding the building configuration, windows, doors, light fixtures, exterior shading devices, over hang dimensions. The output is in graphical format, which is easy to interpret. It gives analysis on energy-efficiency and lighting. The figure 3.6 shows the graphical output of The Decision Desktop, that allows building designers to compare multiple alternative design solutions with respect to multiple design considerations, as addressed by the analysis and visualization tools and databases linked to the BDA.

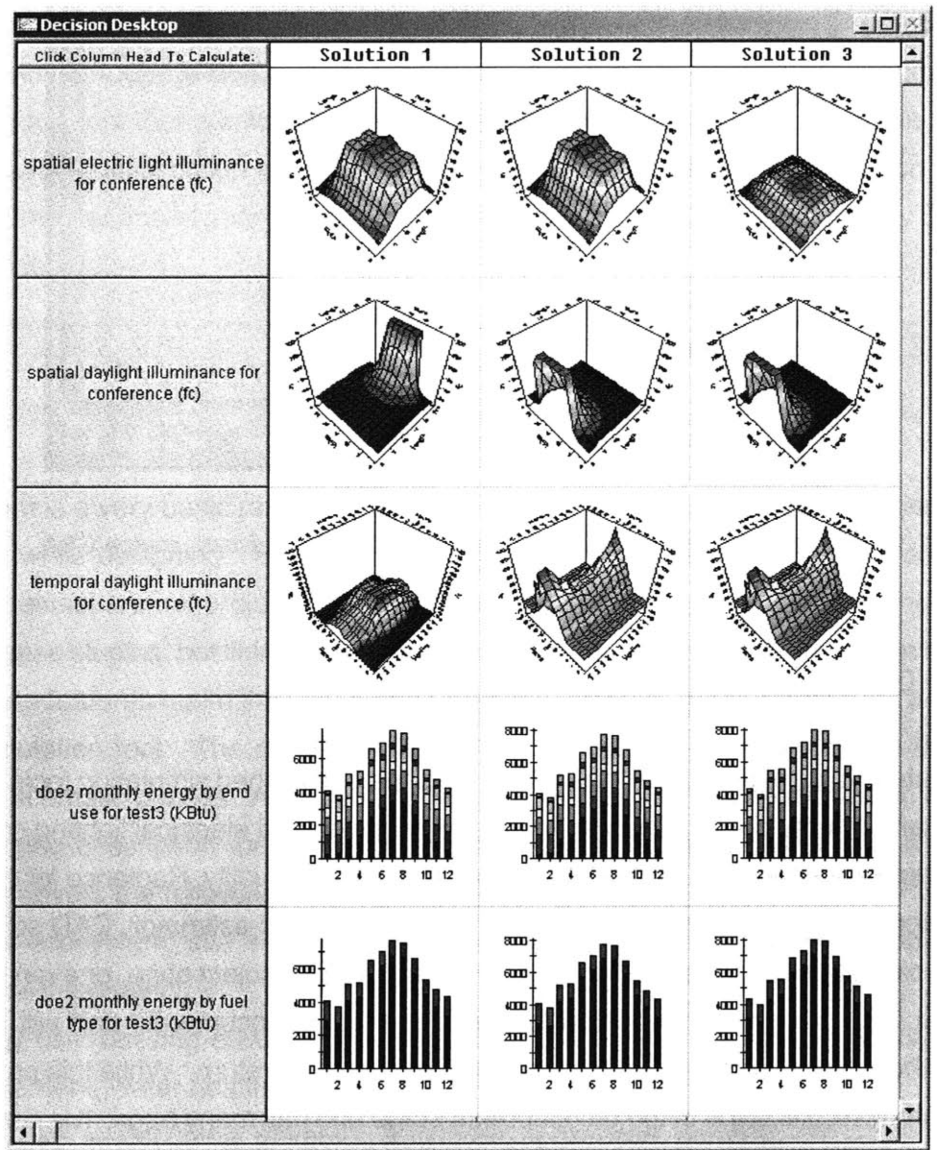

Figure 3.6 Results of Building Design Advisor, source BDA

Energy Scheming

This program is limited to the Macintosh computer, which makes it less accessible to many firms. The main benefit is that it is easy to learn and use, which makes it a useful tool for several design iterations, especially during the schematic design phase. The primary users would be a student or designer for both residential and non-residential projects. A graphical model can be built in the program, drawings scanned in, or CADD drawing file imported. The output is in the form of graphs, and text, regarding energy-efficiency analysis. The building description data requirementsare:

Square feet; roofs: area, pitch, slope, materials, color, mass, r-value, lag time, decrement values, absoptivity/conductance values;

Floors: area, type materials, solar zone, r-value;

windows: percent operable, transmittance, tilt, shading coefficients for shading devices, cross and stack ventilating inlets and outlets, stack height, obstructions, exterior shades, Interior shades, cross ventilation, night ventilation;

Massing material;

Occupant zone: area, density and type, schedules;

Equipment zones: area, quantity and type, schedules;

Lighting: zones, area, levels, fixture types, schedules;

Walls: area, orientation, solar zone, grade line, materials, color mass type, r-value, lag time, decrement values, absorptivity/conductance values;

Interior gains: people, equipment, electric light

Notes

[1] Hensen, J.L.M. & J.W. Hand, 3rd European Conference on Architecture, *Solar energy in architecture and urban planning*, Commission of the European Communities, Florence, May 1993, p354
[2] Newton, D., James, R. and Bartholomew, D., *Building energy simulation - a user's perspective*, Energy and Buildings, 10, p241-247, 1988

[3] Nall, D. H., *Building energy simulation and the architect,* In Building Energy Simulation Conference Notebook, Proc. of the Building Energy Simulation Conference, Wednesday, August 21, 1985, Seattle, p45-48, 1985

[4] Winkelmann, Fred and Kathleen Ellington, Simulation Research Group Building Technologies Program, CBS Newsletter Winter 1996, p4
[5] Trusty, W.B., J.K. Meil, G.A. Norris, *Eco-Indicators for Products and Materials* - State of Play '97: An International Workshop, Sustainable Materials Institute,
[6] Coldham, Bruce, *What is Green Architecture?*, www.coldhamarch.com/green/what
[7] Trusty, W.B., J.K. Meil, G.A. Norris, *ATHENA, An LCA Decision Support Tool for the Building Community*, Sustainable Materials Institute
[8] Center for Renewable Energy and Sustainable Technology - http://www.crest.org/
[9] Lawrence Berkeley National Laboratory - http://gaia.lbl.gov/bda/
[10] Energy Studies in Building Laboratory, University of Oregon - http://www.eren.doe.gov/buildings/tools_directory/software/energysc.htm

Green Building Strategies

Buildings are an integration of many interdependent systems: structure, envelope, lighting, mechanical, HVAC, materials, plumbing, telecommunications, security, etc. How these systems relate and work together is key in understanding and designing a green building. According to HOK, "integrated design means capturing the benefits of multiple systems designed to work effectively together rather than separately. For example, overall comfort can be raised and energy consumption reduced if site design, lighting, window fenestration, air delivery systems, and furniture are thought of together rather than as discrete parts of the project."[1]

Architecture is a process of creating buildings, which means making decisions based on cost, feasibility, project constraints, aesthetics, and in the case of green building, the consequences to the environment. One of the inherent problems of green building is that there are many different technologies, strategies, materials, and methods from which to choose. In addtion, according to Mauritz Glaumann, "the quality of environmental problems has changed from mainly local and evident towards more diffuse, complex and invisible, such as magnetic fields, greenhouse effect, radioactive radiation and harmful solar radiation. This complexity and invisibility complicates the decision of which measures to take."[2] It is important to set priorities for each project to figure out which efforts will do the most good. For example, the embodied energy of building materials is perhaps ten to one hundred times less important for global warming than burning fuels for heating buildings.[3] Establishing priorities will provide the critical direction needed by the project team in order to guide their decision-making process. Therefore, there needs to be a way to prioritize these strategies and technological choices. According to Hal Levin, "Rarely, if ever, is analysis conducted to evaluate trade-offs made among environmental features considered important in 'green' buildings even though conflicts occur among design features intended to improve a building's environmental performance. One 'green building' feature may reduce certain environmental impacts while increasing others. A method is needed to examine the total environmental impact of designs."[4] Prioritizing environmental effects of buildings forces designers to rethink their design process.

As part of a study conducted for this thesis, 220 different strategies were compared between five guidelines and rating tools. (See Appendix J for full comparison) The strategies were then summarized into a survey given to MIT's Green Building Task Force[5] to establish what sustainability concepts and objectives are most important to MIT. The purpose of this survey was to establish an objective methodology for prioritization.

The categories of concentration are divided into Site and Land Use, Water, Materials and Natural Resources, Energy, Indoor Environmental Quality, and Waste and Pollution Prevention. Within each of these categories, several specific strategies were listed. The participant was asked rate (from 1 to 5), each strategy's importance to MIT in terms of environmental and occupant health issues, and to disregard cost as a criteria. The scores were correlated to a matrix (Table 4.2), that associates the effects of the strategy with respect to the related categories of environmental impact, natural resource, occupant health, and community.

There were 12 participants in the following disciplines: 3-Landscape/Planning, 2-Facilities/Construction, 2-Environmental Policy, 1-Indoor Air Quality, 3-Utilities/HVAC, 1-Building Technology. The reason to include a cross-disciplinary group of participants was to take advantage of the expertise of the whole project team. A person in the landscape profession would undoubtedly have a better perspective regarding strategies that relate to site and land use, just as an engineer would have more technical knowledge in HVAC issues.

The tallies were then averaged within each discipline. The following Table 4.1 is an example of one of the strategies within the Site and Land Use category. The results show that the total number of points from the landscape and planning professionals was 12, out a possible total of 15, since there were 3 persons responding. Therefore the average rating from the landscape was 4, out of a possible rating of 1 to 5. Which means they thought understanding the site was a high priority for MIT. The facilities rated this strategy with an average score of 4.5 points, etc.

1.1. Understanding the Site - use microclimate and environmentally responsive site design strategies; schedule construction to minimize sit[e] impact; opt to reuse an existing building rather than build on new site, [o]r opt to demolish and reuse the site of an existing building.		
Discipline	Total	Average
Landscape, Planning	12	4
Facilities, Construction	9	4.5
Environmental Policy	6	3
IAQ	3	3
Utilities, HVAC	7	2.3
Bldg Technology	3	3
Total Score:	**40**	
Average Score:		3

Table 4.1 Sample of Green Building Task Force Survey, Site Category

The averaged scores were then correlated to a matrix (Table 4.2), that associates the effects of the strategy with respect to the related environmental categories of:

- Environmental Impact
  - Greenhouse gas Emissions
  - Local Air/water/Soil Quality
  - Biodiversity/Restoration
- Natural Resource Effectiveness
  - Resource Depletion
  - Energy Efficiency
  - Material Recycling
- Occupant Health
  - Indoor Environmental Quality
- Community
  - Urban Environment

The Table 4.2, on the following page provides a breakdown of the results in terms of the strategies used and the corresponding points awarded. Included is a scale of the impact relevant to the local, regional or global environment.

Related Environmental Categories								Some Relevance / High Relevance / Maximum Relevance			
Environmental Impact			Natural Resource Effectiveness			Occupant Health	Community		Scale of Impact		
Greenhouse Gas Emissions	Local Air/Water/Soil Quality	Biodiversity/ Restoration	Resource Depletion	Energy Efficiency	Material Recycling	Indoor Environmental Quality	Urban Environment	**As Demonstrated By:**	Global	Regional	Local
								Understanding the site			
								Building to site relationship			
								Sustainable landscape practices			
								Alternate transportation			
								Water Conservation			
								Water Reuse			
								Raw Material Extraction			
								Distribution			
								Design			
								Installation			
								Eventual Reuse or Waste			
								Renewable sources			
								Site and massing considerations			
								Interior layout & spatial design			
								Building envelope			
								Daylight and sun control			
								Light pollution			
								Efficient lighting			
								Electrical systems and equipment			
								Mechanical systems			
								Energy load management			
								Air conditioners & ventilation controls			
								Design efficient systems			
								Indoor air quality			
								Source control			
								Ventilation			
								Ventilation control systems			
								Construction methods and precautions			
								Occupant activity control			
								Light source			
								Noise control			
								Conserving resources			
								Waste management			
85	57	30	71	82	19	70	34	TOTALS			

Table 4.2 Results from Green Building Task Force Survey

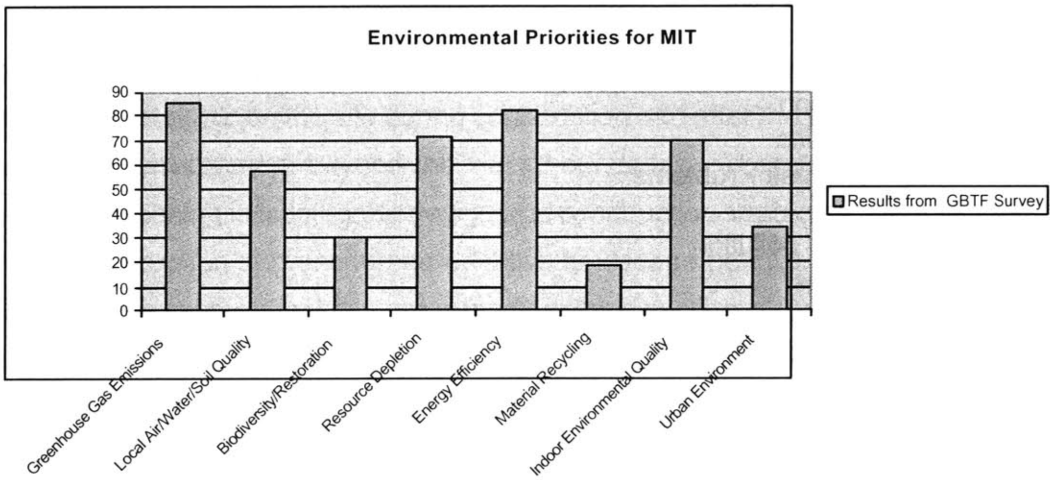

Table 4.3 Results from Green Building Task Force Survey

The results in Table 4.3 show that the highest environmental concerns at MIT, as defined by the Green Building Task Force, are greenhouse gas emissions and energy efficiency, with resource depletion and indoor environmental quality a close 3rd and 4th. These conclusions can be used as the driving information for the overall vision statement for the institution and the guiding principles of the project. This process should be repeated for each individual project to determine the specific priorities for the client, building site and project type. The following principles could be written from the results of the survey above:

Principle 1: Reduce Greenhouse Gas Emissions
Principle 2: Conserve Energy
Principle 3: Minimize Use of New Resources
Principle 4: Respect for Users
Principle 5: Respect for Site
Principle 6: Respect for Community

As a comparison, the following is a ranking of issues that are important in the US, as defined by scientists in the Ecology and Welfare Subcommittee of the U.S. Environmental Protection Agency's Science Advisory Board.[6]

Relatively High-Risk Problems:

- Habitat alteration and destruction
- Species extinction and overall loss of biodiversity
- Stratospheric ozone depletion
- Global climate change

Relatively Medium-Risk Problems

- Herbicides/pesticides
- Toxics, nutrients, biochemical oxygen demand, and turbidity in surface waters
- Acid deposition
- Airborne Toxics

Relatively Low-Risk Problems:

- Oil spills
- Groundwater pollution
- Radionuclides
- Acid Runoff to surface waters
- Thermal pollution

It is noticeable that separate entities have different issues to consider and therefore the rankings should differ. This is true of different projects within the same company, or institution. According to Environmental Building News, there are four critical factors. First is developing an understanding of what the most significant environmental risks are. For example, which is worse, the release of toxic waste, the destruction of an endangered species' habitat, or stratospheric ozone depletion? The second critical factor is an understanding of how the buildings contribute to those risks and how significantly the measures adopted can help the situation. The third factor is related to the specific opportunities presented by each individual project. And the fourth is the consideration of the available resources and agenda of the client.[7]

The rest of this chapter outlines specific strategies that when employed together, can contribute to a greener project. Since it only makes sense to discuss specific strategies in terms of a climate region and building type, for the purposes of this thesis, the strategies are related to MIT buildings, prioritized in order of main concern, as was determined by the survey given to the Green Building Task Force. Throughout the categories, design, construction, and maintenance issues are discussed.

Site

All the activities that occur on the site during construction and after the building is complete are linked to the environment beyond the site's boundaries. Therefore, the purpose of sustainable site planning is to integrate design and construction strategies that will result in minimized site disruption and encourage effective landscape practices. One of the most important decisions in green architecture is made in the selection of the site, before design even begins. "The impact of the project on the regional energy supply networks, water supply and treatment, waste streams, traffic patterns and counts, existing civil infrastructure and other site-specific concerns is evaluated against life-cycle cost criteria and environmental planning and design requirements."[8] Locating new developments on existing brownfield sites and in urban infill areas may also have economic benefits since the infrastructure and services may already be in place. The goal is to identify the ecological characteristics of the site, determine whether it is appropriate for its proposed use, and design ways to integrate the building with the site. The following Table 4.3 lists site design strategies that are applicable to MIT. The strategies listed here, and on the following pages are from the results of the survey given to MIT's Green Building Task Force.[9]

	Strategy
Site & Land Use	
1	**Building-Site Relationship**
	Schedule construction to minimize site impact
	General site layout - consider issues of building mass, orientation, outdoor spaces, passive principles, sun and shade patterns, landscaping
	Mitigation of negative impacts - reduce heat island effect, avoid adverse impacts on adjacent properties, avoid light pollution
	Site lighting - use solar power, efficient lighting, reflective surfaces
2	**Sustainable Landscape Practice**
	Planting practices - use native trees, shrubs and plants, avoid allergy-causing plants near bldg. intakes, avoid invasive species, reduce dependence on fertilizer, consider drip irrigation systems
	Soil quality - provide facilities for composting of landscape materials, use mulch to conserve soil moisture, allow clippings and leaves to decompose on the ground
	Resource use - use recycled, renewable and locally available materials for landscape features
3	**Encourage Alternate Transportation**
	Promote use of alternate & public transportation - include bus stop seating areas & bicycle amenities
	Provide alternative fueling facilities
	Carpool incentives
	Create pedestrian pockets
4	**Understanding the Site**
	Site selection - maintain and enhance the biodiversity and ecology of the site, consider building footprint to minimize the impact on natural resources
	Use microclimate and environmentally responsive site design strategies - preserve natural contours of site, understand the impact of design on nature by a comprehensive site analysis

Table 4.3 Strategies for MIT - Site and Land Use

Water

In the United States, approximately 340 billion gallons of fresh water are withdrawn from rivers, streams, reservoirs, and wells to support our activities in buildings, agriculture and recreation, 65% of which is returned after use and/or treatment. [10] Water conservation, efficiency and management results in decreased demand on the local water supply and treatment facilities. This in turn can result in monetary savings in water-use and discharge fees. For example, in a typical 100,000 square foot office building, low-flow fixtures and equipment can save 1,000,000 gallons of water per year or more, based on 650 building occupants each using an average of 20 gallons per day.[10] Water conservation and reuse are the two strategies most important at MIT.

	Strategy
Water	
1	**Water Conservation**
	Chillers - select based on water conservation criteria; avoid one pass systems
	Use efficient water heating and recirculation systems to conserve water
	Work with natural drainage systems - supplement with detention/retention ponds and/or filtration systems when necessary
	Indigenous landscaping
	Water use/pollution prevention - provide porous surfaces for run-off drainage, filter storm water through plantings and soil, harvest rainwater, do not use chemical pesticides
	Water efficient landscaping - limit or eliminate the use of potable water for landscape irrigation.
	Ozonation - consider ozonation in commercial laundering, and condenser water systems
	Fixture and fitting selection - use low-water or waterless fixtures, automatic shut-off controls, and metered faucets, consider the use of biocomposting toilets
2	**Water Reuse**
	Site retainage of rainwater - reduce rainwater runoff from the site, roofs, and building surfaces to minimize stress on sewer system and to divert and reduce water pollution
	Irrigation and specialty use water - use systems that maximize efficient use of pressurized water and use high efficiency irrigation technologies
	Rainwater use - collect and use rainwater
	Gray water use - collect and use gray water for water closets and urinal flushing
	Excess groundwater - recover excess groundwater from sump pumps for use as a source of recycled water
	Steam condensate - collect and use utility district steam system condensate for non-potable uses
	Vacuum-assist systems - consider a 'vacuum-assist' system for flushing of water closets and urinals

Table 4.4 Strategies for MIT - Water

Building Materials

Building materials play a significant role in sustainable design because of their impact both on the environment and on human health. The locations and manners in which they are extracted, transported, manufactured and packaged have many global implications at each stage of their life-cycle. Building materials can contain toxins that can harm workers during installation, or users long after construction is complete. New green building materials have entered the market recently, many of which are economically competitive with their conventional equivalents. There are several publications and web-sites devoted to environmentally benign material choices such as the AIA's Environmental Resource Guide, and the Environmental Building News' GreenSpec. It is important to realize that an assemblage of green materials in itself does not necessarily make a green building. Rather, it is the way in which they are designed into the project that is important. The building design and specifications, installation, construction and eventual reuse or demolition are all deciding factors in the success of a sustainable building.

Reusing an existing building minimizes habitat destruction, uses infrastructure that is already in place, reduces solid waste and saves landfill space. But it may not be the most efficient in terms of energy use, so care must be taken while making these decisions. Table 4.5 displays strategies for material and natural resource use.

	Strategy
Materials & Natural Resources	
1	**Design**
	Use materials with low environmental impact during their life cycle - conduct a life-cycle analysis
	Material conserving design and construction - design for adaptability and disassembly
	Size buildings and systems efficiently
	Design and detail efficiently to reduce waste generation
	Use materials that are long-lasting and low maintenance
	Eliminate unnecessary finishes
	Design for storage & collection of recyclable
2	**Installation**
	Use low VOC-emitting materials
	Use materials that contain no CFC's, HCFC's, or halons
	Use of Reclaimed or Recycled Materials and Components
3	**Eventual Reuse or Waste**
	Reuse and recycle building components and materials
	Reuse and rehabilitate existing structures
	Use materials that are reusable, recyclable or biodegradable
4	**Raw Material Extraction**
	Use salvaged and remanufactured materials
	Use recycled content products and materials
	Use materials that are harvested or extracted without ecological damage
	Use materials that are made of certified sustainable and renewable resources
5	**Distribution**
	Use locally manufactured materials

Table 4.5 Strategies for MIT - Materials and Natural Resources

Energy

There are three fundamental strategies to a plan that optimizes energy performance: reduce demand, use renewable energy sources, and maximize efficiency. Reducing demand means careful design. When in the planning stage of the project, time should be spent writing a program that is consistent with the client's needs. Many times a building is much larger than it needs to be, which not only uses more energy to heat and cool, but also more materials to build.

Fossil fuels are used for about one third of energy production in the US.[11] Oil and coal fuel requires extraction, refining, power generation and distribution, which result in significant environmental impacts. The production of electricity from coal releases carbon dioxide, which contributes to global warming. It also produces nitrogen oxides, a contributor to localized smog, and sulfur dioxide, which contributes to acid rain. Also when considering the environmental impact, there is an amount of energy wasted through the inefficiencies in generation and transmission between a power plant and the end user. Accounting for transmission loss may include siting the building close to existing services, or on-site generation such as fuel cells, or in the case of MIT, the use of a co-generation plant.

The HVAC systems improvements usually offer the greatest potential for energy savings in most facilities. An example of maximizing energy efficiency is to size the HVAC equipment for *actual* use, which also derives a first-cost savings. The following Table 4.6 outlines twelve detailed strategies relevant to energy use and efficiency.

	Strategy
Energy	
1	**Daylighting/Sun Control**
	Glazing - specify glazing with high visible transmittance and integrate placement to avoid glare
	Consider the design and use of monitors, clerestories, photocell-dimming sensors, light shelves, courtyards and atriums and fiber-optics to encourage daylight into the space
	Provide daylighting integrated with electric lighting controls
2	**Design Efficient Systems**
	Use of energy-efficient appliances with timing devices
	Best practice commissioning - verify and ensure the entire building is designed, constructed, and calibrated to operate as intended with third party quality control assurance
	Optimize energy performance - achieve increasing levels of energy performance above the prerequisite standard to reduce environmental impact associated with excessive energy use
	Measurement and verification - provide for the ongoing accountability and optimization of building energy and indoor environmental quality (IEQ) performance over time

Table 4.6 Strategies for MIT - Energy

	Strategy
Energy	
3	**Energy Load Management**
	Energy management system - use independent advanced control system or for all building controls
	Maximize efficiency of electric power and distribution, and service water heating
	Monitoring and controls - use controls that optimize system response to building pickup and download, energy consumption monitoring using hourly graphs, load shedding and peak electric demand reduction through scheduled equipment cycling, local controllers capable of independently managing equipment operation and gathering data for reporting
	Selection of control method components - use a building automation system to improve the efficiency of HVAC system
	Systems integration - assess the interactions between the HVAC equipment and other related systems, such as lighting, office equipment, etc.
	Computerized control system - use a computerized control system to establish, maintain and document building climate conditions with a backup system in place
	Heating equipment - when reviewing options for boilers, consider oxygen trim controls, draft control inducers, demand control based on variations in heating demand, water reset control keyed to outside air temperature, burner flame control
4	**Mechanical Systems**
	Performance improvement - determine overall environmental impact of building energy consumption, maximize mechanical systems performance
	Systems integration - consider all programmatic and architectural features when sizing HVAC units
	Zoning - use separate HVAC systems to serve areas with different hours of occupancy, perimeter vs. interior spaces, special occupancies, and spaces with different exposures
	Natural ventilation - consider natural vs. mechanical ventilation during swing seasons
	Distribution systems - analyze the benefits of variable air volume systems
	Gas heater/chiller - consider the use of a combination gas heater/chiller
	Distributed mechanical rooms - consider independent mechanical rooms on each floor to reduce ductwork and enhance the balance of delivered air
	Consider the use of heat recovery systems -
	Partial load conditions - select high efficiency equipment that operates at high efficiencies under both full and partial load conditions
	Modular boilers - consider installation of multiple modular boilers that allow more efficient partial-load systems operation
	Do not use CFC/HCFC refrigerants
	Consider the use of condensing boilers
	Chiller sizing - evaluate various sizes and models of chillers to identify units that will most efficiently meet demand requirements; avoid over sizing of cooling and heating equipment which can reduce efficiency
	Desiccant dehumidification - consider desiccant dehumidification as an alternative to the conventional practice of overcooling outside air to remove latent heat prior to removal of sensible heat
5	**High Performance Lighting**
	Lighting power density - design for efficient light source distribution low ambient lighting levels with task lighting fixtures that provide significant illumination of ceilings and walls
	Use high efficiency lamps and luminaires with electronic ballasts, efficiency-based controls, and lumen maintenance controls
	Fixture uniformity - install lower wattage lamps with more frequency

Table 4.6 Strategies for MIT - Energy

	Strategy
Energy	
6	**Air conditioners, chillers, and ventilation controls**
	Generate energy consumption profiles that identify occurrences of peak loads and develop responsive management strategies for reducing utility bills
	Set up the HVAC building control system to operate based on need, if multiple sources are available, minimize simultaneous heating and cooling, and supply thermal conditioning from the most appropriate/efficient sources
	Limit electrical demand during peak hours by turning off non-essential equipment
	Establish temperature and humidity set points based on occupancy patterns, scheduling and outside climate and seasonal condition
	Consider CO2 and VOC sensors to reduce outside air ventilation in large spaces with variable occupancy
	Provide sensors that are capable of adjusting the ventilation rate based on the number of people present in a room
	Provide adaptive, programmable thermostats capable of automatically adjusting settings based on recorded demand patterns
	Set supply air-temperature reset controls for variable air volume systems based on space occupancy
7	**Site and Massing Considerations**
	Solar access - orient the building to maximize solar opportunities and minimize unwanted solar heat gain
	Prevailing winds - orient the building to minimize thermal loss due to infiltration and maximize opportunity for natural ventilation
	Tree locations - locate so that deciduous trees block summer sun and evergreens block winter wind
	Topographical modifications - consider earth forms, berming to optimize thermal mass and/or insulation
8	**Building Envelope**
	Use passive solar design strategies
	Design for natural ventilation
	Envelope detailing - avoid thermal bridging, detail the material assembly with best vapor barrier practices
	Reduction of convective heat losses from unplanned air flows - reduce unwanted stack effect, plan air pressure relationships between rooms as necessary
	Radiant cooling - for internally loaded buildings
	Use of low-embodied energy materials
9	**Electrical Systems and Equipment**
	Equipment specification - specify energy efficient equipment, such as those with Energy Star Labels, and use of lcd computer displays screens
	Distortion minimization - use harmonic filters to minimize the distortion effects of non-linear loads
	Efficient motors - consider premium efficiency motors, controls and variable frequency drives
	Direct current utilization - use direct current from photovoltaic systems, fuel cells when applicable
	Avoid electromagnetic pollution/exposure - install electromagnetic field shielding
	Videoconferencing - design for the use of videoconferencing to avoid unnecessary travel
10	**Light Pollution**
	Reduced night lighting needs - limit lighting to zones where it is necessary for safe passage to entry and exit areas, control by timers and motion sensors
	Proper cut-off angles - use outdoor lighting fixtures with cut-off angles that prevent light from shining upward or too far beyond the intended area of illumination
11	**Interior Layout/Spatial Design**
	Program zoning - group similar program functions in order to concentrate similar heating/cooling demands and simplify HVAC zoning loads
	Use passive zoning design as buffers
	Layout for natural systems - configure occupied spaces to optimize natural ventilation and daylighting
	Stairs - provide inviting staircases to encourage the use of stairs rather than elevators in low-rise buildings
12	**Use Energy Sources with Low Environmental, Impact**
	Renewable energy resources - consider the use of building-integrated photovoltaic panels, daylighting, active and passive solar collection systems
	Super-efficient, hybrid and emerging technologies - consider the use of geothermal heat pump, fuel cell, and heat recovery systems

Table 4.6 Strategies for MIT - Energy

Indoor Environmental Quality

Green building is not just about protecting the environment, conserving natural resources, or saving energy to reduce heating and cooling bills. It also considers the impact of the space on the users of the building. Since the EPA has estimated that in the U.S. we spend as much as 90% of our time indoors,[12] it makes indoor environmental quality (IEQ) one of our greatest health concerns. Good IEQ includes effective air quality including natural ventilation, access to natural light and exterior views, optimum thermal comfort and air temperature, minimum exposure to VOC's, appropriate noise levels, and individual controls. The benefits of attention to these issues include energy and operational savings, improved health and employee morale.

There have been numerous studies that show a correlation between healthy environments and increased productivity. For example, the cost of operating an average federal building, including the amortized construction cost, is about $15 per square foot annually, and the cost of the federal government employees in those buildings is about $315 per square foot per year. If there were an increase of productivity of just 5% by improving the working environment, the annual savings would *exceed* the annual cost of the building ownership and operation.[13] In another example, 19 employees of the U.S. Environmental Protection Agency sued and won $1 million, citing sick building syndrome that caused building related illnesses and multiple chemical sensitivities.[14]

	Strategy
Indoor Environmental Quality	
1	**Light Sources**
	Daylighting apertures - maximize daylighting through appropriate location and sizing of windows, roof monitors, and skylights, and through use of glazing systems and shading devices appropriate to orientation and space use
	Light levels - achieve a good balance between uniform light levels and localized variations to create a dynamic and comfortable visual environment; consider low-level ambient lighting augmented by high quality, flexible task lighting, varied lighting schemes that respond to general building organization and special features, allowing the lighting patterns to reflect changing activity scenarios during the working day
	Luminaire arrangements - arrange luminaires in types and patterns that clearly respond to the fundamental building organization, floor layout and entry paths of daylight while allowing for flexibility of space usage, wherever possible, wire luminaires in parallel to the walls with windows so they can be dimmed or turned off row by row
	Diffusers - select diffusers that reduce glare and sufficiently illuminate ceilings and walls to create a visual field similar to prevailing daylight conditions
	Color - provide lamps with high color rendering index, such as tri-phosphor fluorescent lamps
	Ballasts - use high frequency electronic ballasts to minimize flicker as lamps and ballasts wear
	Window cleaning - schedule regular window cleaning to maximize the amount of daylight entering, particularly where windows are close to sources of air-borne dust, fumes or gases that reduce the transmission of light
	Low-energy lighting - to minimize CO_2 emissions arising from energy used for artificial lighting

Table 4.7 Strategies for MIT - Indoor Environmental Quality

	Strategy
Indoor Environmental Quality	
2	**Source control**
	Specify materials with low VOC's and low particulate and odor emissions
	Carbon dioxide (CO2) monitoring - provide capacity for indoor air quality (IAQ) monitoring to sustain long term occupant health and comfort
	Locate and design air intakes to optimize air supply sources for the ventilation system, isolate building air intakes from building exhaust air, vehicular exhaust, cooling tower spray, combustion gases, sanitary vents, trash storage, and other hazardous air contaminants
	Reduce potential pollution sources through effective moisture control
	Source control - evaluate sources of contamination from neighboring buildings and soil contamination such as radon, methane and excessive dampness
	Isolate potential indoor pollution sources
3	**Control Systems**
	Sensors for relative humidity, temperature, and carbon dioxide should be installed as close as possible to where occupants are located
	Locate sensors to cover areas of similar load conditions
	When demand control ventilation systems are used, ensure that carbon dioxide sensors are operating in a reliable manner
	Periodically audit all computer-controlled HVAC systems
4	**Indoor Air Quality**
	Provide ample ventilation for pollutant control and thermal comfort - minimize production and transmission of air pollution.
	Minimum IAQ performance - establish minimum IAQ performance to prevent the development of indoor air quality problems in buildings, maintaining the health and well being of the occupants
5	**Occupant Activity Control**
	Provide views, View space, and Connection to Natural Environment
	Maintain a no-smoking policy
	Designate an Indoor Air Quality manager who receives ongoing IAQ training
	Provide Operable Windows
	Personal control - build in a capacity for personal control over the immediate indoor environment, assure that the global indoor environment is within acceptable limits by bringing air supply points and controls for air quality as close to individual workstations as possible; balance control system advantages against energy use and maintainability
6	**Noise Control**
	Control noise at the source - site, orient and lay out the building such that external noise sources can be attenuated by distance of by topographic features or walls
	Place acoustic buffers, such as corridors, lobbies, stairwells, electrical/janitorial closets, and storage rooms, between noise-producing and noise-sensitive spaces
	Prevent transmission of sound through the building structure through use of floating floor slabs and sound-insulated penetrations of walls, floors, and ceilings
	Prevent transmission between rooms by wall, floor, and ceiling assemblies by specifying materials with appropriate sound transmission class ratings, consider using set-off studs with sound-attenuating insulation, floating floor slabs and sound-absorbent ceiling systems
	Consider wrapping or enclosing rectangular ducts with sound isolation materials
	Consider the use of sound attenuators and acoustic plenums to reduce noise in ductwork
	Absorb or block excessive background noise or interfering single-source sounds in open office environments through use of resilient flooring, ceiling and sound absorbing or reflecting partitions and furniture
	If appropriate conversational privacy cannot be achieved, consider using white noise
	Achieve favorable room acoustics by configuring room geometry, positioning furnishings and furniture, and specifying appropriate surfaces

Table 4.7 Strategies for MIT - Indoor Environmental Quality

Waste

Solid waste disposal has become a critical problem in the US, making up 25% of the waste stream.[15] There are strict regulations regarding landfills due to filled storage capacity, contamination of water sources, noxious odors and public resistance to locating landfill sites in nearby neighborhoods. Construction activities often generate huge amounts of solid waste. This can either be incinerated into landfills, or more appropriately, recycled or re-used on site. The design of the building, choice of materials, ordering of materials with less packaging, the establishment of a waste management plan, and the reuse of on-site materials such as broken concrete all contribute to the ultimate goal of less waste. In addition, due to increased costs of hauling and landfill tipping fees and rising material prices, there can be substantial savings by recycling construction and demolition waste.

	Strategy
Waste & Pollution Prevention	
1	**Conserving Resources**
	Reuse existing buildings
	Design for less material use - use modular dimensioning, and design for minimum square footage
	Specify reuse of on-site materials to the greatest extend possible
	Design building for adaptability - consider issues of site planning, structural systems, standardization or repetition of building elements, cladding systems, floor heights, raised floor systems, modular interior planning
	Design building for disassembly - consider issues of structural systems, cladding systems, materials, durability, snap release components, modular systems
2	**Waste Management**
	Salvage and recycle demolition waste
	Recycle construction waste
	Reduce and recycle packaging waste
	Reduce and properly dispose of hazardous materials waste
	Provide waste-separation facilities for building users
	Provide waste-separation facilities for hazardous materials
	Educate workers and occupants on recycling, waste reduction and prevention

Table 4.8 Strategies for MIT - Waste and Pollution Prevention

Sustainable architecture by definition is region specific, so the following 'top-ten' lists should be thought of as general guidance. Each project would demand that reorganization of any priority-list. Most of the lists have the same strategy suggestions, but vary in the order of importance. Architecture, and sustainability, are still subjective sciences, therefore, there is not one single answer to the design solution.

Massachusetts Institue of Technology Top Ten List for Sustainability

Site and Land Use:
1. Consider the building to site relationship
2. Practice sustainable landscape
3. Encourage alternate transportation
4. Select the site wisely

Water:
1. Conserve and reuse water

Materials and Natural Resources:
1. Design for material conservation and recylability
2. Use healthy building materials
3. Use materials with low environmental impact
4. Use locally manufactured materials

Energy:
1. Design with daylighting
2. Design efficient systems
3. Consider energy load management
4. Design mechanical systems efficiently
5. Use high-performance lighting
6. Consider air conditioners, chillers and ventilation controls
7. Consider site and massing issues
8. Design for efficient building envelope
9. Consider electrical controls for motors and equipment
10. Reduce light pollution
11. Design interior layouts efficiently
12. Use energy sources with low environmental impact

Indoor Environmental Quality:
1. Design light sources with good light levels, arrangements and color rendering
2. Reduce indoor pollutant sources
3. Provide controls sytems CO_2 emissions, and load conditions
4. Provide ample ventilation
5. Provide occupant control over immediate environment
6. Control noise during construction and occupation
12. Use energy sources with low environmental impact

Waste and Pollution Prevention:
1. Conserve natural resources by reusing existing buildings, designing for less materials and adaptability and disassembly

Environmental Building News Priority List for Sustainability

1. Save energy – design and build energy-efficient buildings
2. Recycle buildings – utilize existing buildings and infrastructure instead of developing open space
3. Create community – design communities to reduce dependence on the automobile and to foster a sense of community Reduce material use – optimize design to make use of smaller spaces and utilize materials efficiently
4. Reduce material use – optimize design to make use of smaller spaces and utilize materials efficiently
5. Protect and enhance the site – preserve or reserve ecosystems and biodiversity
6. Select low-impact materials – specify low-environmental impact, resource-efficient materials
7. Maximize longevity – design for durability and adaptability
8. Save water – design buildings and landscapes that are water-efficient
9. Make the building healthy – provide a safe and comfortable indoor environment
10. Minimize construction and demolition waste – return, reuse, and recycle job-site waste and practice environmentalism in your business
11. Green up your business – minimize the environmental impact of your own business practices, and spread the word

AIA Checklist for Environmentally Sustainable Design and Construction

Design:
1. Smaller is better
2. Design an energy-efficient building
3. Design buildings to use renewable energy
4. Optimize material use
5. Design water-efficient, low-maintenance landscaping
6. Make it easy for occupants to recycle waste
7. Look into the feasibility of graywater and rooftop water catchment systems
8. Design for future reuse
9. Avoid potential health hazards: radon, EMF, pesticides

Siting & Land Use:
1. Renovate older buildings
2. Evaluate site resources
3. Locate buildings to minimize environmental impact

4. Pay attention to solar orientation
5. Provide responsible on-site water management
6. Situate buildings to benefit from existing vegetation
7. Minimize transportation requirements

Materials:

1. Avoid ozone-depleting chemicals in mechanical equipment and insulation
2. Use durable products and materials
3. Choose materials with low embodied energy
4. Buy locally produced building materials
5. Use building materials made from recycled materials
6. Use salvaged building materials when possible
7. Minimize use of old-growth timber
8. Avoid materials that will give off gas pollutants
9. Minimize use of pressure-treated lumber
10. Minimize packaging waste

Equipment:

1. Install high-efficiency heating and cooling equipment
2. Install high-efficiency lights and appliances
3. Install water-efficient equipment
4. Install mechanical ventilation equipment

Job Site & Business

1. Protect trees and topsoil during sitework
2. Avoid use of pesticides and other chemicals that may leach into groundwater
3. Minimize job-site waste
4. Make your business operations more environmentally responsible

Pennsylvania's What is a High Performance Green Building

1. A project created via cooperation among building owners, facility managers, users, designers and construction professionals through a collaborative team approach
2. A project that engages the local and regional communities in all stages of the process including design, construction and occupancy
3. A project that conceptualizes a number of systems that, when integrated, can bring efficiencies to mechanical operation and human performance
4. A project that considers the 'true costs' of a building's impact on the local and regional environment
5. A project that considers the 'life-cycle costs' of a product or system—these costs associated with its manufacture, operation, maintenance and disposal
6. A building that creates opportunities for interaction with the natural environment and defers to

contextual issues such as climate, orientation and other influences

7. A building that minimizes demolition and construction wastes and uses products that minimize waste in their production or disposal
8. A building that is energy and resource efficient
9. A building that can be easily reconfigured and reused
10. A building with healthy indoor environments
11. A project that uses appropriate technologies, including natural and low tech products and systems, before applying complex or resource intensive solutions
12. A building that includes an environmentally sound operations and maintenance regimen
13. A project that educates building occupants and users to the philosophies, strategies and controls included in the design, construction and maintenance of the project

Governor's Green Government Council Ten Simple Things You Can Do

Planning:

1. Get involved in a region's local policy review and development process
2. Redevelop existing urban areas
3. Encourage higher density developments
4. Encourage pedestrian circulation
5. Plan developments to be in harmony with the area's natural environment
6. Plan developments in response to the historic and cultural context
7. Protect hydrological systems from development
8. Manage storm water runoff and quality
9. Locate development within appropriate topographical areas
10. Locate development within appropriate vegetative areas

Architecture

1. Establish an energy budget
2. Optimize the design of the building envelope
3. Use high efficiency standards for electric lighting
4. Design for good indoor air quality
5. Use water efficient plumbing fixtures
6. Investigate building materials
7. Manage storm water
8. Use suitable plant material
9. Plan for occupant recycling
10. Recycle construction waste

Interior Design

1. Design for flexibility

2. Maximize use of natural daylight
3. Set high lighting efficiency standards
4. Design for good indoor air quality
5. Reuse existing materials, use less materials, and specify environmentally responsible building materials
6. Specify energy-efficient and water saving appliances
7. Use water efficient plumbing fixtures
8. Design for ease of maintenance and the use of environmentally friendly cleaning products
9. Make room for building recycling facilities
10. Recycle demolition and construction waste

Green Building Digest - Principles of Green Building

Reduce Energy in Use

1. Use maximum possible low embodied energy insulation, but with good ventilation
2. Use low energy lighting and electrical appliances
3. Use efficient, low pollution heating
4. Make use of passive and active solar energy whenever feasible
5. Use passive and natural ventilation systems rather than mechanical

Minimizing External Pollution and Environmental Damage

1. Design in harmonious relationship with the surroundings
2. Avoid destruction of natural habitats
3. Re-use rainwater on site
4. Treat and recycle waste water on site if possible
5. Try to minimize extraction of materials unless good environmental controls exist and avoid materials which produce damaging chemicals as a by product
6. Do not dump waste materials off site but re-use on site

Reducing Embodied Energy and Resource Depletion

1. Use locally sourced materials
2. Use materials found on site
3. Minimize use of imported materials
4. Keep use of materials from non-renewable sources to a minimum
5. Use low energy materials, keeping high embodied energy materials to a minimum
6. Use second hand/recycled materials where appropriate

7. Re-use existing buildings and structures instead of always assuming that new buildings are required

Minimizing Internal Pollution and Damage to Health

1. Use non toxic materials, or low emission materials
2. Avoid fibers from insulation materials getting into the atmosphere
3. Ensure good natural ventilation
4. Reduce dust and allergies
5. Reduce impact of electromagnetic fields (EMF's)
6. Create positive character in the building and relationship with the site
7. Involve users in design and management of building and evaluating environmental choices

Notes

[1] Mendler, Sandra, Odell, William, *The HOK Guidebook to Sustainable Design*, John Wiley & Sons, Inc. 2000, p19

[2] Glaumann, Mauritz, and Wolfram Trinius, *Environmental Assesment of Buildings A research project in co-operation with the building sector*, Sweden, June 6, 1996

[3] Curwell, March & Venables, *Buildings & Health – The Rosehaugh Guide to the Design, Construction, Use & Management of Buildings*, RIBA Publications, 1990

[4] Levin, Hal, *Ten Basic Concepts for Architects and Other Building Designers,* Environmental Building News, 13 Jul 200, *http://www.buildinggreen.com/elists/halpaper.html*, p1

[5] As of July of 1999, there is a newly established Office of Environmental Management (EMO) at the Massachusetts Institute of Technology. Their charge is to lead campus environmental initiatives at MIT. One of the initiatives is to examine MIT's own process of building in terms of sustainability. Together with the facilities department, the EMO created a *Green Building Task Force* (GBTF). The goal of the task force is to produce green building guidelines that will establish principles, processes, and strategies that will lead to the construction and renovation of buildings on campus that are environmentally sustainable.

[6] *Reducing Risk: Setting Priorities and Strategies for Environmental Protection,* The Report of the Science Advisory Board Relative Risk Reduction Strategies Committee to the EPA, September 1990.

[7] *Establishing Priorities with Green Building*, Environmental Building News, Volume 4, No. 5 – September/October, 1995

[8] *Guidelines for Creating High-Performance Green Building Guidelines*, Pennsylvania Department of Environmental Protection, 1999, pD4

[9] The six strategies charts, Site and Land Use, Water, Materials and Natural Resources, Energy, Indoor Environmental Quality, and Waste and Pollution Prevention are primarily based on information from the comparison study, found in Appendix J

[10] *LEED Green Building Reference Guide*, US Green Building Council, August, 2000, p50

[11] *LEED Green Building Reference Guide*, US Green Building Council, August, 2000, p69

[12] Environmental Protection Agency, http://www.epa.gov/iedweb00/

[13] *Greening Federal Facilities, An Energy, Environmental, and Economic Resource Guide for Federal Facility Managers*, Department of Energy, Produced by Greening America, 1997, p2

[14] *LEED Green Building Reference Guide*, US Green Building Council, August, 2000, p118

[15] *LEED Green Building Reference Guide*, US Green Building Council, August, 2000, p159

The Building Process

When facilitating a green design process, there are two main factors at play: information and process. While it is important to employ green-building guidelines, sustainability tools, and specific design strategies, (*Chapters 2 - 4*), without a good understanding and awareness of the vast amount of 'green' information available, and a procedure to incorporate it into the building process, sustainability concepts cannot be realized or fully developed. The process requires that every decision be examined with respect to its impact upon human health and the environment. The critical key to accomplishing this is an integrated design approach, where the evaluation of any building element, material or system is designed and then appraised as an integrated part of the entire building, and not viewed solely on the basis of its own isolated merit and cost. Under an integrated design approach, specific materials or systems within a facility may have higher first costs, but these can be balanced by lower first costs for other components of the design. According to the Navy, "the goal is to design a facility for which overall quality is higher, life-cycle costs are lower, sustainability concepts and principles are incorporated to the greatest extent possible, and first costs are held to the original budget amounts."[1] There is a need to know what decisions to make in each part of the process, and a need to have a mechanism in place to transfer that knowledge to future projects. This gives the design team the information required to know what actions to take at the critical stages, before it is too late to change the direction of the project. This chapter outlines a green building design, construction, and maintenance process that integrates green concepts into all aspects of building. Traditionally, the process is a linear one progressing from design to construction to occupancy. But this linear mode of thinking does not allow for future opportunities for the building, the environmental consequences, or the full life-cycle cost implications of long-term investments in the building project.

Another change that is taking place in the profession is the advent of 'object-based' software that promises to link architecture, engineering, construction, and facilities management applications into an integrated language and database. This process ties together architectural and engineering drawings, specifications, project budgets and schedules so that each profession has access to the same information at the same time. Examples of this are in place at Disney Corporation, where they have developed standards for their consultants to follow. With environmentally-conscious design, this is an especially useful tool for understanding the relationships between all of the design considerations and the budget.

There are many ways to divde the building process. In the Introduction to Sustainable Design, by the National Pollution Prevention Center for Higher Education, there are three main phases.[2] The first, Pre-building Phase includes site selection, building design, building material processes and installation. The second, Building Phase, refers to the stage of a building's life cycle when a building is physically being constructed and operated. The third, the Post-building Phase, begins when the useful life of the building has ended. For the purposes of this thesis, the building process has been divided into the following phases:

1. Project Inception & Feasibility: Pre-design
2. Concept Approval: Schematic Design
3. Development Permit: Design Development
4. Building Permit: Construction Documents
5. Award of Construction Contract: Bidding or Negotiation
6. Construction Administration: Construction
7. Substantial Performance Occupancy Permit & Warranty and Maintenance: Post-construction and Occupancy
8. Building Reuse or Demolition

Project Inception & Feasibility: Pre-design

One of the biggest frustrations of architects desiring to design sustainably, is that by the time they are hired, many major decisions have already been made. Feasibility studies, site selection, and project budgeting are typical examples. These choices have extensive repercussions and can be especially important to basic green building concepts. For example, after consulting with a team of informed green building professionals, it may be determined that the best choice for a new building is to renovate an existing one. Or the implementation of innovative and ultimately cost-saving green technologies most likely has to be accounted for in the initial budget. Often, budgets are set too low, and thereafter the project team must labor to include green concepts within that budget. While it is traditionally the architect that leads the design and consultant team, it is becoming more common for the client to hire engineering professionals (and other consultants) directly. It is often the case in large projects that the client hires a project facilitator to manage and direct the project, even at the design phase. This is not a problem when the client takes the initiative to realize a green building, but that is an infrequent occurrence.

The following Table 5.1 is a list of the architectural responsibilities involved in the pre-design stage of a project.[3] Checkmarks are denoted next to the tasks that are conducive to incorporating green concepts.

Project Inception & Feasibility: 1.0 Pre-design			
Architect's Services		**Special Consultants Services**	
x	Assemble Green Team	x	Land Survey
x	Develop Green Vision	x	Geotechnical Analysis
x	Establish Green Design Criteria	x	Environmental
x	Set Priorities	x	Urban Planning
x	Develop Performance Based Building Program	x	Collect Site Data
x	Facility Programming	x	Municipal Bylaw Review - (Historic, Creeks, Hazardous Materials, etc.)
x	Space Relationships	x	Project Scheduling
x	Flow Diagrams		Legal Survey
x	Establish Project and Energy & Lighting Budget		Foreign Practices Review
x	Project Development/Scheduling		
x	Life Cycle Cost Studies		
x	Economic Feasibility Studies		
x	Site Selection/Analysis/Utilization		
x	Environmental Studies		
x	Energy Studies		
x	Existing Facilities Surveys		
	Agency Consulting/Review/Approval		
	Client-supplied Data Coordination		
	Project Management		
	Presentations		
	Marketing Studies		
	Project Financing		
	Special Studies		
	Re-zoning Assistance		
	Project Promotion		
	OCP/Zoning Review		
	Obtain Consultants Proposals		

Table 5.1 Pre-design

The first step is to set performance goals for the project. This is in the form of a project-specific mission statement that reflects the client's vision, and a set of environmental and economic priorities to which the project team can refer while making decisions. Team formation is the next key step in producing a green building. Decisions made by each stakeholder may influence the intents and aspects of performance sought by other key stakeholders of the project. In addition to the architect, the environmental design team preferably includes a facilitator, the project owner, building users and manager, a cost estimator, engineers, energy simulation consultant, general contractor, and major sub-contractors. When the project involves major urban redevelopment, the public should also be invited to participate. When each member of the project team is involved at the beginning, it is easier to ensure that future decisions will be made based on the initial green concept goals. Early participation also creates an environment of communication between all the parties involved. This will establish interdependence within the team that will influence the success of a high performance building throughout all the phases of the design, construction and operations of the building's lifetime. Bill Reed of the Hillier Group puts it this way, "Whole system design analyzes every building system and integrates them so that the whole is greater than the sum of the parts. This process requires every member of the design team to understand and help address the issues of every other member of the team. An example is the mechanical and electrical engineer looking to the architect to help the building reduce its energy load. The architect may respond with a design that invites more natural daylight into the building in order to reduce the electrical lighting loads. The engineers may then be able to reduce the mechanical system sizing significantly."[4]

A good way to create green concepts at this stage is to hold an environmental design charrette. This is where invited parties meet to brainstorm and share ideas and develop concepts for the project. According to the Green Buildings BC, a charrette is "an intense workshop in which all project team members come together to set goals and generate design ideas. This workshop, or series of workshops, takes place in the early phase of the project's design. The performance targets are referred to throughout the charrette to steer the goal-setting process and to ensure that key building features meet the requirements. This process is crucial in establishing team consensus on the project specific performance targets and the goals, mission statement and key elements of the project."[5] The outcome of the charrette should produce many ideas from which the design team can proceed. These ideas should then be compared against the project performance goals set by the client. This is also the phase where time should be spent gathering information regarding energy and resource conservation, building ecology, environmental approaches to landscaping, waste prevention and reclamation, cultural change and behavioral issues, and regional scale planning. As part of planning the scope, magnitude and direction of an energy-efficient project, it is necessary to predict the operation, usage, maintenance and energy consumption patterns of the intended building. Through looking at this information, it is possible to examine the magnitude of energy efficiency opportunities, and target areas for energy conservation and efficiency changes. Project scheduling is also an opportunity to ensure that there is enough time to conduct environmental and energy studies, to run energy and building simulations, and to explore sustainable options at the start of the project. In addition, this is the time to schedule commissioning for the building. Too often, the project runs behind schedule and this very important task is overlooked.

Concept Approval: Schematic Design

Green architecture is recognized to be a "front-end loaded" process, because the opportunities for green design are the greatest at the beginning of the project. This is especially true at the schematic stage. According to Bruce Coldham, Architect, "the schematic design phase should occupy roughly 40% of the design, rather than the conventional 25% because systems and envelope design are so interrelated with massing and siting."[6] In addition to the architect, the schematic design phase may include an energy engineer or specialty consultant to promote the best possible solution in terms of high performance design. Many basic decisions made in this phase have far reaching consequences that cannot be rectified at a later time. The building siting, massing, orientation, envelope, daylighting and natural ventilation design decisions have major environmental impacts and economic consequences. Functional and programmatic issues such as efficient use of space, shared services, building flexibility, adaptability and access are all issues that need to be considered. Therefore, a team knowledgeable in sustainable strategies at this phase is imperative. Green building guidelines such as LEED, are a helpful tool to use as a platform for discussion and a basic checklist for possible suggestions to green design strategies. (See Chapter 2, *Green Building Guidelines and Rating Systems*)

Ideally, a few schematic design solutions are worked out, and can be reviewed for cost and feasibility. As Theresa Coady says, "Typically, building designers tend to work independently in their respective areas of expertise. With conventional building designs, the structure is first massed out, elevations are developed, and finally, the building systems are added. The obvious drawback to this process is that building designs sometimes become a tangle of mis-matched systems, interacting poorly with one another, the site and creating potential problems for occupants."[6] This means that the structural, mechanical, electrical, plumbing, interior design and landscape design concepts should be thought about in an integral manner.

The British Columbia Building Corporation, for example, has developed eight key steps in the design phase process. Within each step design goals are set, team members are identified and their role is defined. Each stage allows for extensive computer modeling to provide feedback on the effects of the design decisions and to provide a quantitative basis

Concept Approval: 2.0 Schematic Design			
	Architect's Services		**Coordination of Normal Engineering Services**
	Client-Supplied Data Coordination	x	Structural Design Concepts
x	Program and Budget Evaluation/Review	x	Mechanical Design Concepts
x	Review Site Characteristics	x	Electrical Design Concepts
x	Confirm Green Design Criteria	x	Statements of Probable Costs
x	Develop Green Solutions		Agency Consultation
x	Review Alternate Design Approaches		Building Code Review
x	Architectural Schematic Design	x	Value Analysis
x	Document Green Materials and Systems		**Special Consultants Services**
x	Check Cost		Geotechnical Design Concepts
x	Schematic Design Coordination		Civil Design Concepts
x	Drawings & Documents	x	Landscape Concepts
x	Review Construction Contract Types		Statements of Probable Costs
x	Statement of Probable Construction Costs		Building Code Review
	Client Consultation		Zoning Amendments
	Agency Consultation		Zoning Variance
	Building Code Review		Municipal Bylaw Review
x	Interior Design Concepts		Foreign Practices Review
x	Special Studies; e.g. Future Facilities, Environmental Impact		OCP/ Zoning Analysis
	Special Submissions or Promotional Presentations	x	Traffic Studies
	Special Models or Perspectives	x	Urban Design/Streetscape
	Project Management	x	View/Sun/Shadow Studies Area Analysis
x	Value Analysis		
x	Building Envelope Professional Services		

Table 5.2 Schematic Design

upon which to measure projected performance. They also employ a thorough cost performance study to allow team members to see how their changes affected the overall cost of the building and the owner to see how operating cost savings would accumulate.[8]

In addition to the typical schematic design presentation of drawings and models, additional information should be presented to the client to support a green proposal. This would include projected energy and water consumption, and the proposed selection of building materials. In addition, the design strategies must be compared based on preliminary life cycle costs. This will enable the client to base their decisions on the complete existence of the building, rather than on first costs alone. Sandra Mendler of HOK & Associates suggests, "to negotiate a contract requiring specific deliverables, such as an energy budget and energy modeling, an indoor environmental quality and resource conservation report, and even life-cycle analysis of building materials."[9] The Table 5.2 details the steps involved in the schematic design phase of the project.

Development Permit: Design Development

At this phase, the chosen schematic design scheme is developed further. This includes the process of analyzing every decision, system, component, and aspect of the design in respect to the green-concept goals set earlier. It entails evaluating many design and system options so that the most promising solutions can be selected. Such issues as designing for efficient use of materials are thought about in this phase. Materials that are recycled and reused within the project or bought reused, eliminating unnecessary ornamentation, designing for durability, and careful detailing are also issues to consider at this time. In the *Sustainable Design Guide*, this is called optimization and is compared to a financial budget. "We can not imagine starting a project without a clear understanding of the budget. The status of the project budget is the subject of numerous checks throughout the design process and is generally a part of every project meeting. In contrast, an energy budget is rarely understood, much less commonly discussed and evaluated as part of the design process."[10] The *Guidelines for Creating Green Buildings* puts it this way, "One purpose of design optimization is to scrutinize the large, over arching goals set at the beginning of the project to see if the effort is on track. Another is to take advantage of each additional opportunity that presents itself as the project evolves."[11]

Design development is a good time to employ simulation tools, which may prompt redesign and refinements. Building simulation is a useful tool for analyzing the energy performance of a building for understanding the relationship between the design parameters and energy use of the building. According to the Green Buildings BC New Buildings Program, computerized energy modeling allows important feedback to the design team concerning the estimated performance of the proposed design. It is also used as a constant update on the projected savings of various design solutions so that they can be appropriately contrasted with other solutions. Energy modeling allows feedback so that the design team can find solutions that have the lowest life-cycle cost. Effective application of building simulation requires understanding the nature of the issue to be solved, choosing a suitable simulation program, interpreting the simulation results, and making decisions. Other imperative tasks at this time are life-cycle analysis (LCA) and life-cycle cost analysis (LCCA). Total life-cycle costing (TLCC) includes techniques that take into account initial costs and future costs and benefits (savings) of an investment over some period of time. See Chapter 3, *Sustainability Assessment Tools*, for a detailed explanation of simulation and life-cycle analysis tools.

A common complaint regarding creating a high performance building is that they are sometimes more expensive. While this may be true, the lowest initial cost for green materials and technologies may not be the best in terms of the life-time of the building. Many times, when the true costs are considered, the project is much less expensive. Table 5.3 shows the green-concept strategies that can be employed during this phase.

Development Permit: 3.0 Design Development			
	Architect's Services		**Coordination of Normal Engineering Services**
	Client-Supplied Data Coordination	x	Structural Design Development
	Design Coordination	x	Mechanical Design Development
x	Perform Energy Simulations	x	Electrical Design Development
x	Refine Green Solutions	x	Budget Review/Evaluation
x	Perform Life Cycle Analysis	x	Statements of Probable Costs
x	Perform Life Cycle Cost Analysis		Agency Consultation
x	Architectural Design Development		Building Code Review
x	Design Development Coordination	x	Value Analysis
x	Drawings & Documents		**Special Consultants Services**
x	Statement of Probable Construction Costs		Geotechnical Design Development
	Client Consultation		Civil Design Development
	Agency Consultation	x	Landscape Design Development
	Building Code Review	x	Detailed Construction Cost Estimates, Quantity Surveys
	Development Permit Submission		Fire Protection
	Budget Review/Evaluation	x	Acoustics
	Certified Professional Service		Building Code Equivalencies
x	Interior Design Development		Certified Professional Service
x	Special Studies Reports; e.g. Planning Tenant or Rental Spaces	x	Energy Utilization Studies
	Promotional Presentations	x	Building Envelope Professional Services
	Models or Perspectives		
	Project Management		
	Rezoning Variance Submission		
x	Value Analysis		
x	Building Envelope Professional Services		

Table 5.3 Design Development

Building Permit: Construction Documents

Although the tangible impacts are visible only after construction begins, decisions made on the drawing board have long-term environmental consequences. Construction documents, consisting of drawings and specifications are still the main method of recording the building process. They convey the intent of the designer and are instructions to the contractor to build the project. Therefore, it is crucial that these documents also communicate the green vision and goals set by the owner and project team. This is the last opportunity to revisit the project before it gets reviewed by the planning department for a building permit. After this, all changes must go through a change-order process.

The drawings ideally should include a statement of intent and a description of how the building systems are to perform. Pennsylvania's Guidelines recommend the creation of a performance program at this time. "Its purpose is to document the overall strategy for integrating the parameters of the project. These typically include such things as budgets, site utilization, space planning, integrated building systems, occupancy issues and other specific needs or goals of the project. The performance program also sets forth the target limits for many of these systems."[12] They emphasize the importance of documenting the integrated systems in drawing format. For example, this could be a drawing that explains the relationship between a raised-floor air distribution system and the wiring and ductwork in the same space. Drawing such as these would alert the team when there are modifications to the original drawings, and in turn reduce the chance of making changes that would irrevocably alter the green design intent.

The specifications also need to be carefully written as to relay the appropriate information. The conventional system of using the Construction Specifiers Institute (CSI), Divisions 1 through 16, does not allow for certain green methods such as construction waste management, and building commissioning. Therefore, additional information needs to be included regarding issues such as coordination of the structural systems with assembly and disassembly considerations, fabrication methods, material packaging, delivery and building component construction strategies. Table 5.4 outlines the services of the architects and denotes the green strategies that should be employed.

Building Permit: 4.0 Construction Documents			
Architects Services		**Coordination of Normal Engineering Services**	
	Client-Supplied Data Coordination	x	Structural Construction Documents
	Project Coordination	x	Mechanical Construction Documents
x	Review Green Design Intent	x	Electrical Construction Documents
x	Architectural Construction Documents (Working Drawings, Form of Contract and Specifications)	x	Statements of Probable Costs
x	Include Construction Waste Management & Commissioning in CD's		Building Code Review
x	Include Building System Integration Drawings		Letters of Assurance
x	Document Checking and Coordination		Budget Review/Evaluation
x	Statement of Probable Construction Costs		Building Permit Submissions
	Client Consultation	**Special Consultants Services**	
	Agency Consultation		Geotechnical Documents
	Building Code Review		Civil Construction Documents
	Letters of Assurance		Detailed Construction Cost Estimates, Quantity Surveys
x	Budget Review/Evaluation		Fire Protection
	Coordinating Registered Professional Role	x	Acoustics
	Building Permit Submission		Building Code Equivalencies
	Certified Professional Service		Certified Professional Service
x	Interior Construction Documents		Energy Utilization Analysis
	Alternate Bid Details & Special Bid Documents		Security System Design
	Project Management		Existing Condition Surveys
	Area Analysis	x	Building Envelope Professional Services
	Project Lease Plans		
	Tenant Layout Drawings		
	Multiple Contracts Management		
	Phased Construction Management		
	Building Envelope Professional Services		

Table 5.4 Construction Documents

Award of Construction Contract: Bidding or Negotiation

The most fundamental way to ensure the project will follow the intended green mandate is to include the objectives of the design team in the language of the request for proposal (RFP). This will automatically advise the prospective architect that the selection team will give priority to those firms with experience in green design. Many times architectural firms will just include the name of an energy consultant with whom they usually partner, but that should not be enough. Unless the firm has proven experience in green design, they may not be sufficiently skilled in the distinctive process of green design.

Another initial barrier to realizing a green building is in the fee structure. Typically there is a pressure for agencies and clients to accept the lowest bid. This practice, usually mandated by law for government projects, is adversarial and affords poor results. It does not consider the long-term benefits of many energy-saving technologies, nor does it account for the externality costs to the city and to the population. In the Pennsylvania's Guidelines, it describes as a "system wherein design professionals and consultants are paid a percentage of the project cost provides little incentive to work creatively to reduce project costs while keeping design standards high."[13] Typically, a percentage-based fee for services rendered is charged to the client. A better method would be a negotiated contract, where the contractor or supplier works closely with the design team from the beginning. The criteria for selection should be the same as for other professionals, for their skill and experience.

Award of Construction Contract: 5.0 Bidding or Negotiation			
	Architect's Services		**Coordination of Normal Engineering Services**
	Client-Supplied Data Coordination		Prepare Bid Documents
x	Issue RFP with Green Language		Prepare Addenda
x	Documents Relating Green Concepts to Bidders	x	Bid Evaluation
	Coordinate Issue of Bid Documents		**Special Consultants Services**
	Coordinate/Issue Addenda		Prepare Bid Documents
x	Bid Evaluation		Prepare Addenda
	Client Consultation		Bid Evaluation
	Prepare Contracts		Prepare Prequalification Criteria
x	Consider Non-percentage Based Contracts		Prequality Contractors
	Separate Bids or Negotiated Bids		
	Services Related to Bidders Proposals		
	Project Management		
x	Prepare Prequalification Criteria		
	Prequality Contractors		

Table 5.5 Bidding or Negotiation

Especially in the case of the mechanical engineer, the percentage-based fee can work counter to producing a green building. If the fee is tied to the size of the HVAC system, there is the possibility that it will be unnecessarily over-designed. A similar situation can occur with the structural system, in that many times the structure is over-designed due to liability reasons. The structural engineer and architect are responsible for the integrity of the building; therefore the rationale is that it's better to be safe than sorry. Unfortunately, though, this does not contribute to a project built with minimal resources in mind. The solution is to account for a fee that reflects the importance of the participation of the engineers and consultants in the initial stages of the project. This could be accomplished on a time and materials basis while the scope of the contract is being defined, then in a lump sum for the duration of the project.

Construction: Construction Administration

If the contractor was involved as part of the project team early on in the project, then the chances for breakdown at this phase are less. The problems start to arise when the contractor is just introduced to the project at this phase and is unfamiliar with the intent of the design team, and can worsen if he is unfamiliar with green construction methods. It is common for the contractor to have a regular group of sub-contractors with which he works, and a standard way of doing business. Many times the contractor is reluctant to try new techniques or to hire new subcontractors with expertise in green technologies. It is necessary to convey the importance of keeping the green vision and goals intact while the project is under construction. A way to avoid this is to hire the construction firm as part of the design team up-front. This can be either with the intention of retaining the firm for the project, or by a fee for service consult, followed by taking the project out to bid as usual. The benefits of this are many. The contractor can work with the design team to work out the detailing, which will reduce the amount of potential change orders during construction. They can also offer the services of their cost-estimator to make sure the project stays on budget while considering different green technologies and options. Critical also, is to include the major sub-contractors and vendors in the design process. This will minimize the pressure to substitute conventional products for specified green products. They may even be able to suggest better alternatives if they are familiar with the green concept goals of the project. In any case, there needs to be great attention to reviewing shop drawings and product data to make sure they are in conductive to the goals of the project. The Table 5.6 outlines the responsibilities of the architect during this phase.

Construction: 6.0 Construction Administration			
	Architect's Services		**Coordination of Normal Engineering Services**
	Construction Inspection/Field Review		Structural Inspection/Field Review Reports
	Progress Reports Evaluation	x	Mechanical Inspection/Field Review Reports
	Certificates for Payment		Electrical Inspection/Field Review Reports
	Interpretation of Contract Documents		Certification of Progress
x	Educate All Sub-contractors to Green Priorities		Letters of Assurance
x	Shop Drawing/Product Data/Sample Review	x	Record (As-Built) Drawings
x	Review All Submittals and Requests for Alternates to Maintain Green Priorities		**Special Consultants Services**
x	Change Orders & Change Directives		Civil Construction Inspection/Field Review
x	Review of Warranties (1)	x	Landscape Inspection/Field Review
	Client Consultation	x	Detailed Cost Accounting
	Letters of Assurance	x	Fire Protection Inspection/Field Review
	Coordinating Registered Professional Role	x	Acoustical Inspection/Field Review
	Substantial Performance Report and Certification (1)		Building Code Equivalencies
	Deficiency Assessment (1)		Certified Professional Service
	Instructions for Correction of Deficiencies (1)	x	Building Envelope Professional Services
	Final Inspection and Certification for Payment (1)		
	Agency Consultation		
x	Interior Construction Inspection/Field Review		
	Full-Time Project Rep		
	Admin. of Separate Contracts		
	Project Management		
	Promotional Material		
x	Record (As-Built) Drawings		
	Certification re: Financing		
	Alternate Dispute Resolution Services		
	Certified Professional Service		
	Multiple Contracts Management		
	Phased Construction Management		
	Building Envelope Professional Services		
	Payment certifier role for subcontracts (Lien legislation)		

Table 5.6 Construction

Substantial Performance Occupancy Permit and Warranty & Maintenance: Post Construction

Building commissioning, post occupancy evaluation, and life-cycle cost monitoring are the major green concept activities at this phase of building. In a study of the cost effectiveness of commissioning 44 existing buildings, high rise offices and retail establishments had an average simple payback of 1.6 years. Medical institutions averaged 0.4 years, and computer facilities had a 0.3 year payback period.[14] Therefore, building commissioning is a very cost-effective strategy in green building. Post-occupancy evaluation is important to ensure that the users of the building are comfortable in their environment. Many times the design or technology does not work as intended. A good example of this procedure is the Vital Signs Project, in Berkeley, California. The Vital Signs Curriculum Materials Project examines the physical performance of buildings, their patterns of energy use, and their impact upon occupant well being.[15]

Commissioning is a quality process for achieving, validating and documenting that the facility and its systems are planned, designed, installed, tested and capable of being operated and maintained to perform in conformity with the design intent. The process extends through all phases of a new or renovation project, from conceptualization to occupancy and operation, with checks at each stage of the process to ensure validation of their performance to meet the owner's design requirements.[16]

Substantial Performance Occupancy Permit & Warranty and Maintenance: 7.0 Post-Construction			
Architects Services		Coordination of Engineering and Special Consultants Services	
x	Project Inspection/Field Review		Start-Up Assistance
	Deficiency Assessment		Services Provided After Substantial Performance Date
	Instructions for Correction of Deficiencies		Non-Building Equipment Selection
	Start-up Assistance		Building Analysis and Reports
	Services Provided After Substantial Performance Date		Services Related to Alterations and Demolition
	Fine Arts/Crafts/Graphics/Non-Building Equipment Selection	x	Life Cycle Cost Monitoring
x	Building Analysis and Reports Services Related to Alterations and Demolition	x	Systems Performance Review
x	Life Cycle Cost Monitoring	x	Commissioning
x	Environmental Monitoring		
	Project Management		
x	Commissioning		
	Alternate Dispute Resolution Services		
	Expert Witness Services		
x	Post-Occupancy Evaluation		

Table 5.7 Post-construction

Building Demolition or Reuse

Many times a building is demolished without consideration for reuse. The most sustainable building is one that has been renovated for a new use. Unfortunately in the US, the building's life span is thought of in terms of mortgage and lease-years. In Europe, for example, buildings have stood for centuries, adopting a new use with the evolving needs of the society. The actions to take at this phase are evaluating the building to identify reuse, recycling, and salvage potentials at the building and component scales. This includes assessment of the spatial, structural, programming, economic, environmental and human factors related to reuse or decommissioning.

Demolition or Building Reuse: 8.0 Post-occupancy			
	Architects Services		**Coordination of Engineering and Special Consultants Services**
x	Evaluate the building to identify possibility for renovation	x	Hire a demolition contractor with experience in waste management
x	Evaluate the building to identify possibilities for salvage potential for building assemblies and components		
x	Evaluate the building for material recyclability		
x	Develop a Reuse and/or a Salvage Plan		
x	Encourage good site maintenance during demolition		

Table 5.8 Post-occupancy

Even with a clearly defined process in place, there are many barriers to designing a sustainable building. In her study, "Breaking through the Barriers to Sustainable Building", Miriam Landman from Tufts University concluded that the main obstructions are: lack of interest or demand from clients, lack of training/education amoung designers, failure to account for long-term benefits, and higher first costs, real or perceived.[17] Amory Lovins of the Rocky Mountain Institute lists the following obsticles:[18]

Developers control the design choices, but typically desire fast, cheap buildings that favor appearance over long-term value, and rarely take energy efficiency into account.

Lenders are rewarded for closing deals as quickly as possible, and do not have the time or inclination to study innovative design.

Commercial appraisers tend to not know about energy systems, thereby reinforcing developers and lenders short-term priorities.

Designers, architects and engineers frequently work in isolation and rarely does anyone take responsibility for the entire enteractive system.

Mechanincal and electrical equipment is often grossly oversized due the the fear engineers have of their jobs, or being sued.

The best designs often require an investment of time for learning new methods.

The prevailing fee structure and bidding system is tied to a percentage of the project's cost which allows for oversizing and inefficiencies.

Contractors operate on a fixed budget and are rewarded for cutting corners, so they routinely try to substitute materials.

And finally, landlords do not have any incentives to upgrade their buildings without a financial payback.

Notes

[1] Naval Facilities Engineering Command Planning and Design Policy Statement – 98-01 *Design of Sustainable Facilities and Infrastructure*, 18 June 1998, p4

[2] National Pollution Prevention Center for Higher Education, *Introduction to Sustainable Design*, December 1998, pg 22-26

[3] This chart is based on information from the AIA's Descriptions of Designated Services for the Agreement Between Owner and Architect, the *Sequence of Scope and Services Chart* by the Architectural Institute of British Columbia, and the *Pennsylvania's Guide to Creating High Performance Green Building Guidelines*

[4] Reed, Bill, AIA, The Hillier Group, *A Whole Systems Approach to Building, Lessons Learned Four Times Square*, p39

[5] Green Buildings BC New Buildings Program Design Process for Pilot Projects, www.greenbuildingsbc.com

[6] Coldham, Bruce, *What is Green Architecture?,* www.coldhamarch.com/green/what

[7] Coady, Theresa & Zimmerman, Alex, *It's the Process, Not the Gadgets!*, Green Building Challenge, 1998

[8] Green Buildings BC New Buildings Program Design Process for Pilot Projects, www.greenbuildingsbc.com

[9] Mendler, Sandra, AIA, Director of HOK Sustainable Design Group, *Be Careful What You Ask For, Lessons Learned Four Times Square*, p41

[10] Hellmuth, Obata + Kassabaum, Inc., *Sustainable Design Guide*, 1998, pv

[11] Pennsylvania Department of Environmental Protection, *Guidelines for Creating High-Performance Green Building Guidelines*, 1999, p5

[12] Pennsylvania Department of Environmental Protection, *Guidelines for Creating High-Performance Green Building Guidelines*, 1999, p7

[13] Pennsylvania Department of Environmental Protection, *Guidelines for Creating High-Performance Green Building Guidelines*, 1999

[14] Pennsylvania Department of Environmental Protection, *Guidelines for Creating High-Performance Green Building Guidelines*, 1999, p11

[15] Vital Signs Project, http://www.arch.ced.berkeley.edu/vitalsigns/Default.htm

[16] Total Building Commissioning General Principles and Procedures, www.sustainable.state.fl.us/fdi/

[17] Landman, Miriam, *Breaking through the Barriers to Sustainable Building*, http://www.tufts.edu/tie/tci/pdf/Miriam1.pdf

[18] Lovins, Amory, *Institutional Inefficiency*, IN CONTEXT #35, Spring 1993, p16

The Project Plan

All of the tools listed thus far have important roles in green building, but there are more things that can and should be done for all projects. This last chapter outlines specific action items that an architectural firm, corporation, or university could implement to establish a prevailing approach to sustainability for buildings. It is important to stress that all of these items are hollow without buy-in from the decision-makers and a commitment of resources. Without the support of the principals or the administration, it would be next to impossible to implement a standard practice of green building and design. An allocation of funding is necessary so that there is room for experimentation, success and failure. As Jim Duderstadt, President of the University of Michigan, says, "Sometimes we can learn as much from a spectacular failure as a stunning success."[1] The victory of furthering the status of sustainability requires visionary leadership, as well as the allegiance of the firm, and in the case of universities, the faculty, staff and student body. This involves the challenge of motivating people to change, a change in the standard way of doing business, a change in attitude about our role in nature, and a change in our capacity to produce results.

Elements of a well-rounded sustainable project approach include:

- Objectives
  - Mission Statement
  - Project Goals and Priorities
- Information
  - Research
  - Library of Case Studies
  - Green Resources Website
  - History Guide of Projects
  - Presentations and Lectures
  - Training for Building Users
  - Marketing for Successful Projects
- Tools
  - Template RFQ and RFP
  - Green Design and Construction Strategies
  - Green Specifications

Cost-benefit vs. Environmental Impact Analysis Tool
Process of Integration Guide

Pilot Projects
Demonstration Buildings
On-going Support
Student Research Teams

Financing Options

Objectives

Mission Statement

A clearly defined mission statement provides a vision that conveys principles that have been adopted by the firm or institution. This is the foundation for introducing the ideals that the firm or university hold most important. It is important that those in positions of responsibility embrace the principles set forth by the mission statement.

Project goals and priorities

Based on the targets of the mission statement, specific goals and priorities need to be established for each project. This will give the design team a reference upon which to refer while making conflicting decisions. In an architectural firm, where projects sites could range in climate zones, and the client is different for each project, the goals and priorities will change.

Information

Library of Case Study Projects

In order to take advantage of the many examples of previously built green projects, a valuable reference tool would be a library of case studies. This should be made available to all the team participants at the start of the project. The case studies should identify attributes of the project to describe the difference between sustainable and traditional construction, means and methods. A cost analysis would be helpful to compare different strategies and benefits.

Green Resources Website

There is an abundant amount of information available on the internet on the subject of green design. An additional important reference tool is a website that provides links to the most current and relevant material available. This would include a directory to help find green products and locate suppliers.

History Guide of Previous Projects

There is an opportunity for project team members to benefit from the experiences of others. Many similar obstacles and challenges have most likely been encountered in a previous project. A project history guide will enable a team member to look up previous successes, thereby avoiding duplication of previous mistakes. It will also assist in the refinement of particular strategies and processes with each subsequent project.

Presentations & Lectures

In order to keep up to date on the most current technologies in green building, lectures and presentations by knowledgeable professionals are indispensable. These could also serve as forums for manufacturers to inform clients of their newest "green" products.

Training for Building Users

Even the most efficiently designed building will fail in its attempts if the users of the building are not sufficiently trained in the technologies employed in the design. Therefore, there needs to be sufficient opportunity for the users to become educated to the intention of the designer. This can be in the form of manuals and training sessions.

Project and Firm Marketing

This is an avenue to publicize the firms' commitment to sustainability to the community at large. One of the greatest advantages of the LEED system is that it is a recognizable rating, and therefore can be marketed as such. The Four Times Square project in New York, for example, has received significant press coverage due to the achievements of the whole project team in high performance building.

Tools

Request for Qualifications and Proposals

One of the initial steps in the building process is to solicit requests for qualifications and proposals from architects and their consultants. In order to alert the prospective project teams to the intentions of a green building, the RFP must include language to that effect. Expertise in the area of green building will then serve as one of the criterion in the selection process. Included in the qualification statement should be documentation of previous green building projects, and a statement of intent from the lead designer describing their philosophy to the project. If the firm does not have prior experience in green building, then a commitment to work with a sustainable consultant could be sufficient.

Request for Information

As part of understanding the scope, magnitude and direction of a project in terms of green building design, it will be necessary to review the proposed design. Therefore, at various phases during the design and construction, it will be helpful to solicit information from the project team regarding their design intent. The overall goal includes gathering information and evaluating design options. Through looking at this information, it will be possible to evaluate the proposed design solutions in the areas of improved health and welfare of the user, natural resource efficiency, and reduced environmental impact of the proposed design.

Green Design and Construction Strategies

The purpose of a strategies guide is to provide a reference to which the design team can refer while making decisions. There are many existing available guidelines that outline specific strategies. One of the biggest challenges is the problem of prioritization. Inherent in these systems are value judgments on what constitutes a “green building”. What is considered “green” in one city or state may not be considered so in another. Other parameters such as site conditions, building types, client preferences and user needs, also call for different design strategies. A good guideline reference is written with a specific climate in mind and allows for variance on a project by project basis. To further customize the strategies, benchmark information regarding resource consumption data for standard buildings, along with the desired projected values, would be included.

Green Specifications

There exist several very good specifications reference tools, such as the AIA's Environmental Resource Guide, and the Environmental Building News' GreenSpec. They are available either by purchasing a CD, or by entering a code via the web. Since this topic is changing almost daily, with new companies and technologies emerging, the internet is an ideal platform for the exchange of information. For example, MIT is in the process of updatin its specifications book to inlcude green building concepts, strategies and technologies. It describes the building systems in a graphical manner that allows for cross-reference between CSI division categories. It will be available for all participants on the project team.

Cost-benefit vs. Environmental Impact Analysis Tool

In many instances, approving a high-performance building alternative is not an option unless it can be shown to be cost-effective. However in order for project leaders to have a basis upon which to make decisions, they must be provided with a full analysis of not only the projected cost implications of a building, but also the full environmental consequences. The quantification of environmental benefits is not always a tangible process, but this will provide the decision-makers with a tool to determine if a green strategy or design is cost-effective and/or environmentally benign. It would include a first-cost and a life cycle cost description, as well as a life-cycle analysis of the materials and processes of the building. For example, Johnson's Controls, Inc. is currently developing a document that describes the expected return on investment from specific provisions listed in LEED. It will describe whether each provision will increase or decrease capital costs or operating costs. It will also categorize the environmental, social, and economic return on investment for each provision.[2]

The reason for this is that there is perception that all green buildings are inherently more expensive and take more time to build than a conventional projects. Three examples of high performance buildings prove that they do not. Four Times Square in New York cost $125 per square foot; SC Johnson Worldwide Professional Headquarters Building in Wisconsin cost $137 per square foot, including the land costs; and the International Netherlands Group Bank Headquarters in Amsterdam was built for $161 per square foot, including the fixtures, furnishing and equipment.[3] These three examples are within a competitive cost range for typical commercial buildings, while providing the economical savings of an energy-efficient building and affording the occupants with a healthier working environment.

Process of Integration Guide

There is an opportunity to integrate green building concepts into every stage of building design and construction. Sustainability presupposes a collaborative interaction between all the participants in a project and a cyclical project delivery process, as opposed to the standard linear model. This could possibly be one of the most important aspects of realizing a green building. Without a clearly identified building process, many opportunities for green design implementation may go unrealized. Ideally, the internal design and construction process of the firm or organization would be analyzed and be modified to include green building concepts.

Pilot Projects

Demonstration Buildings

A demonstration building is a good way to showcase advanced green technologies. But in the long-term view, it is useful for a corporation or campus to focus on particular green design strategies, rather than to try to incorporate all of them in to every project. Through demonstration projects, as well as the other items listed in this chapter, the design team can mainstream selected green building objectives into its clients' facilities.

On-going Support

Green Design Advisory Board

There should be an advisory board or single representative that is knowledgeable in green concepts. This group would be present at design meetings, and be available to the project managers and project team for guidance regarding green concepts and technologies. They would be responsible for reviewing projects after the pre-design, schematic design and design development phases. Additional review may be necessary at other key points based on the needs of the project and design team.

Student Research Teams

In the case of universities, a benefit can be realized from their most valuable resource - the student. Many projects can be developed that could offer an opportunity for the student to learn and to participate in the building process by providing technical assistance to the design team. For example, it could be beneficial for the facilities department to have available a group of students to run simulations of schematic designs.

Financing Options

Financial capital for energy efficient projects is available from many sources, but the key is knowing where to look and what to select. While there may exist several variations, there are five general financing mechanisms for energy-efficient improvements and investments.[4] The appropriateness of these tools depends on the type of firm or institution, the complexity or size of the project, and the expertise of the individuals involved.

- Internal Funds – Energy efficiency improvements are financed by direct allocations from an organization's own internal capital or operating budget
- Debt Financing – Energy efficiency improvements are financed with capital borrowed directly by an organization from private lenders and includes municipal bonds
- Lease or Lease-Purchase Agreements – Energy efficient equipment is acquired through an operating or financing lease of 5 to 10 years with no up-front costs
- Energy Performance Contracts – Energy efficiency measures are financed, installed, and maintained by a third party that guarantees savings and payments based on those savings
- Utility Incentives – Rebates, grants, or other financial assistance are offered by an energy utility for the design and purchase of certain energy efficient systems and equipment

An example of a utility incentive program is Savings by Design, a statewide program in California.[5] It offers technical assistance and cash incentives for the design and production of high performance buildings. The rewards are paid directly to the design teams, intending to encourage participation between architects, MEP engineers, and lighting designers. Incentives are also directed at clients and project owners.

Conclusions

The concept of sustainable design is an important underlying principle of a new method of design thinking. It is not a new style of architecture, rather it is a methodology based on ecological principles. Although society pays for the hidden costs of negligent design through the externality costs of energy production, natural resource depletion, the destruction of habitat ecosystems, the pollution of air, water and soil, and higher health risks caused by the toxic materials and poorly ventilated buildings, it is not the responsibility of society to change the practices of architects. That obligation rests on the design and construction profession. As the designers of the buildings we live and work in, we have the duty and opportunity to lead humanity towards a more sustainable lifestyle. Fundamentally, the client, architect and builder need to make a decision together to contribute to move towards environmental accountability. Once they do, it will only be a matter of time before green design becomes standard practice.

Even with all of the means to make a prediction, a building's performance can only truly be determined after the project is completed. Therefore, by implementing the ideas listed in this thesis, one can only make the assumption that the project will be more energy-efficient, have better indoor quality, and be less detrimental to the environment. But, certainly if the current standard practice of building is not changed, there can be not be a change in the impact architects' designs have beyond the exterior of our buildings.

Notes

[1] As repeated in *Changing a Mind-Set, Not Just a Problem-Set: Sustainable Development in Colleges of Engineering*, Presented at: 1999 Engineering Deans Institute, American Society for Engineering Education, *Ethics in Technology and Social Responsibilities*, March 21-21, Maui, Hawaii

[2] Johnson Controls, Inc. Controls Group, Paul von Paumgarten, paul.vonpaumgarten@jci.com

[3] Browning, Bill, *Putting the Dollars Together: The First Cost Equations of High Performance Buildings*, Green Development Services, Rocky Mountain Institute

[4] Building Resources, *Improving Existing Buildings/Designing New Buildings*, www.eren.doe.gov/energysmartschools/explore_finance

[5]New Program Rewards Energy Efficiency in California Commercial Construction, www.pge.com/savings/home

Appendix A - Background Concepts

Agenda 21

Agenda 21 & Other UNCED Agreements

http://www.igc.org/habitat/agenda21/ Agenda 21 & Other UNCED Agreements

Agenda 21 and Sustainable Development

http://www.iol.ie/~isp/agenda21/ Agenda 21 and Sustainable Development

Agenda 21 - National Information

http://www.un.org/esa/agenda21/natlinfo/index.html Agenda 21 - National Information

Ecological Footprints

Revisiting Carrying Capacity: Area-Based Indicators of Sustainability

http://www.dieoff.com/page110.htm Revisiting Carrying Capacity: Area-Based Indicators of Sustainability

What is an Ecological Footprint?

http://www.esb.utexas.edu/drnrm/WhatIs/ecofootprint.htm What is an Ecological Footprint?

Ecosystem

Complexity and Connectivity in Ecosystems

http://www.csu.edu.au/ci/vol03/klomp/klomp.html Complexity and Connectivity in Ecosystems

Ecosystem Valuation

Ecosystem Valuation http://www.ecosystemvaluation.org/

Green Economics

Green Economics Website

http://www.greeneconomics.net/ Green Economics Website

Sustainability

Applying Sustainable Development

http://www.applysd.co.uk/ Applying Sustainable DevelopmentBest Environmental Resources Directories

Brain Food

http://www.dieoff.com/Brain Food

Center for Renewable Energy and Sustainable Technology

http://www.crest.org/Center for Renewable Energy and Sustainable Technology

Consulting the Public Interest

http://www.cipi.com/artclsus.shtmlConsulting the Public Interest

Deep Sustainability [National Centre for Sustainability (NCFS)]

Deep Sustainability [National Centre for Sustainability (NCFS)]http://www.islandnet.com/~ncfs/ncfs/

Defining Sustainability

http://www.arch.wsu.edu/~sustain/defnsust.htmDefining Sustainability

Department of Energy Library

http://vm1.hqadmin.doe.gov/library/Department of Energy Library

Department of Energy - EnergyFiles

http://www.osti.gov/EnergyFiles/Department of Energy - EnergyFiles

Ecosustainable - Sustainable Environment

http://www.ecosustainable.com.au/links.htmEcosustainable - Sustainable Environment

Environment & Sustainable Living

http://condor.stcloudstate.edu/~dmichael/eco/ Environment & Sustainable Living

Factor Four (abstract)

http://www2.wupperinst.org/Projekte/Factor4_e/FactorFourBook.html Factor Four (abstract)

The Florida Center for Understanding Sustainability

http://www.ficus.usf.edu/The Florida Center for Understanding Sustainability

Indicators of Sustainability Training Course

Indicators of Sustainability Training Course http://www.sustainablemeasures.com/Training/Indicators/index.html Indicators of Sustainability Training Course

Institute of Energy and Sustainable Design

http://www.iesd.dmu.ac.uk/ecadap/ecadap.htmlnstitute of Energy and Sustainable Design

Interagency Working Group on Sustainable Development Indicators

Interagency Working Group on Sustainable Development Indicators http://www.sdi.gov/iwgsdi.htm Interagency Working Group on Sustainable Development Indicators

A Paradigm for Sustainability (by Richard Risemberg)

http://www.living-room.org/sustain/paradigm.htm A Paradigm for Sustainability (by Richard Risemberg)

Sources of Sustainability

Sources of Sustainability http://csf.colorado.edu/elsewhere/index.html Sources of Sustainability

Sustainable Energy Authority

http://www.sea.vic.gov.au/building/ESCB/links.htmlSustainable Energy Authority

Sustainable Measures

Sustainable Measures http://www.sustainablemeasures.com/ Sustainable Measures

The Sustainability Report

http://www.sustreport.org/The Sustainability Report

Towards Sustainability

http://www.towards-sustainability.co.uk/Towards Sustainability

World Bank

http://www.worldbank.org/ World Bank

Sustainable Architecture

Alternative Architecture and Sustainable Development

http://apocalypse.org/pub/u/paul/arch.htmlAlternative Architecture and Sustainable Development

Architecture and Building

http://library.nevada.edu/arch/rsrce/webrsrce/main0018.html#Women2717Architecture and Building

Architecture and Community

http://csf.colorado.edu/sustainability/community.htmlArchitecture and Community

Earthship Architecture

http://www.earthship.org/home.htm Earthship Architecture

Environmental Design and Sustainability

http://www.arch.vt.edu/Sustainability/extras/website.htm Environmental Design and Sustainability

Environmental Sustainable Architecture

http://enertia.com/envirarc.htm Environmental Sustainable Architecture

Green Building Primer

http://www.energybuilder.com/greenbld.htmGreen Building Primer

Green Design Sustainable Architecture

http://www.lib.berkeley.edu/ENVI/GreenAll.htmlGreen Design Sustainable Architecture

The Hannover Principles

http://minerva.acc.virginia.edu/~arch/pub/hannover_list.html The Hannover PrinciplesIntegrated Building Technology

Sustainable Architecture

http://members.aol.com/reidybrown/htmldocs/architecture archpg1.htmlSustainable Architecture

Sustainable Architecture Building and Culture

http://www.sustainableabc.com/Sustainable Architecture Building and Culture

Sustainable Architecture Resource

Sustainable Architecture Resource http://www.umich.edu/~nppcpub/resources/ResLists/arch.html

Sustainable Building Resource

http://www.iris.ba.cnr.it/sustain/welcome.aspSustainable Building Resource

Sustainable Building Sourcebook

http://www.greenbuilder.com/sourcebook/contents.htmlSustainable Building Sourcebook

Urban Sustainability

Database on Good Practice in Urban Management and Sustainability

http://europa.eu.int/comm/urban/

Florida Internet Center for Understanding Sustainability (FICUS)

http://www.ficus.usf.edu/

Green Communities Assistance Kit

http://www.epa.gov/greenkit/

Livable Communities

http://www.livablecommunities.gov/

Living Room

http://www.living-room.org/

Smart Growth Network

http://www.smartgrowth.org/

SURBAN (database on sustainable urban development in Europe)

http://www.eaue.de/winuwd/default.htm

Sustainable Communities Resource Package (SCRP)

http://www.web.net/ortee/scrp/

Sustainable Urban Design and Climate

http://www.bom.gov.au/climate/environ/design/design.shtml

Urban Ecology Australia

http://www.urbanecology.org.au/

Urban Ecology Design Collaborative

http://www.urbanecology.com/

The Virtual Library on Urban Environmental Management

http://www.gdrc.org/uem/Sustainable Urban Design and Climate
The Hannover Principles

Appendix B – Associations and Directories

Associations and Institutions

Aarcosanti: a prototype arcology

http://www.arcosanti.org/

American Indoor Air Quality Council

http://www.iaqcouncil.org/

American Institute of Architecture

http://www.aianewmexico.com/aia_abq/docsb.html

American Solar Energy Society

http://www.ases.org/

Architects, Designers and Planners for Social Responsibility (ADPSR)

http://www.adpsr.org/

Architectural Green Solar Network (AGSN) (Germany)

http://www.agsn.de/

Architecture & Engineering Division, State of Montana

http://www.discoveringmontana.com/doa/aed/index.htm

Association for Environment Conscious Building (AECB)

Association for Environment Conscious Building (AECB)

BASEA - Boston Area Solar Energy Association

http://www.basea.org/

Bioarchitettura (Italy)

http://www.bioarchitettura.org/

Building Concerns

http://www.interiorconcerns.org/

Business for Social Responsibility (BSR)

http://www.bsr.org/

Center for Maximum Potential Building Systems (CMPBS)

http://www.cmpbs.org/

Center for Neighborhood Technology (CNT)

http://www.cnt.org/

Centre for Sustainable Design (CFSD)

http://www.cfsd.org.uk/

Centers for Sustainable Living (CSL)

http://coins0.coin.missouri.edu/community/home-garden/sust-living/

Center for Sustainable Systems

http://www.umich.edu/~nppcpub/index.html

Climate Action Network (CAN)

http://www.climatenetwork.org/

Committee on the Environment (COTE)

http://www.e-architect.com/pia/cote/home2.asp

Contra Costa County Solid Waste Authority

http://www.wastediversion.org/

The Earth Council

http://www.ecouncil.ac.cr/

Ecodesign Foundation

http://www.edf.edu.au/

EcoDesign Resource Society (Canada)

http://www.ecodesign.bc.ca/

Eco-Home Network

http://www.ecohome.org/

Ecological Design Institute (EDI)

http://www.ecodesign.org/edi/

Ecological Living

http://eco-living.net/

EcoRecycle Victoria

http://www.ecorecycle.vic.gov.au/

Environ Design Collaborative

http://www.environdc.com/

Environmental Energy Technologies Division

http://eetd.lbl.gov/software.html

EPA's Environmentally Preferable Purchasing (EPP)

http://www.epa.gov/opptintr/epp

Five E's Unlimited

http://www.eeeee.net/

Florida Green Building Coalition (FGBC)

http://floridagreenbuilding.org/

Green Building Alliance (Pittsburgh)

http://www.gbapgh.org/

Green Building Information Council (GBIC), Canada

http://greenbuilding.ca/

Green Round Table: Sustainable Architecture and Design

http://www.greenroundtable.org/

The Green Center (New Alchemy Institute)

http://www.fuzzylu.com/greencenter/

Green Home

http://greenhome.org/

Green Map System

http://www.greenmap.com/

thegreenpages.ca

http://www.thegreenpages.org/

Green Resource Center, Berkeley

http://www.greenresourcecenter.org/

Green Space Design

http://www.greenspacedesign.org/

The Healthy House Institute (HHI)

http://www.hhinst.com/

Intergovernmental Panel on Climate Change (IPCC)

http://www.ipcc.ch/

International Institute for Sustainable Development (IISD)

http://iisd1.iisd.ca/

Keepers of the Waters

http://www.keepersofthewaters.org/

Low Impact Development Center

http://www.lowimpactdevelopment.org/

National Association of Home Builders

http://www.nahb.org/

National Centre for Sustainability (NCFS)

http://www.islandnet.com/~ncfs/ncfs/

National Councils for Sustainable Development (NCSD)

http://www.ncsdnetwork.org/

National Pollution Prevention Center for Higher Education (NPPC)

http://www.umich.edu/~nppcpub/index.html

Natural Building Resources

http://www.strawbalecentral.com/

The Natural Step (US)

http://www.naturalstep.org/

North East Sustainble Energy Association- NESEA

http://www.nesea.org/

Office of Building Technology, State and Community Programs

http://www.eren.doe.gov/buildings/

Organisation for Economic Co-operation and Development (OECD)

http://www.oecd.org/

Partnership for Advanced Technology in Housing (PATH)

http://www.pathnet.org/

Resource Renewal Institute (RRI)

http://www.rri.org/

Rocky Mountain Institute (RMI)

http://www.rmi.org/

Scottish Ecological Design Association (SEDA)

http://www.inverarc.co.uk/seda/

Second Nature

http://www.secondnature.org/

Society of Building Science Educators

http://www.polaris.net/~sbse/web/sbsehome.htm

Soil and Water Conservation Society (SWCS)

http://www.swcs.org/

Southface Energy Institute (SEI)

http://www.southface.org/

SD (Sustainable Development) Gateway

http://www.sdgateway.net/

Sustainable Development International

http://www.sustdev.org/

Sustainable Living Network

http://www.sustainableliving.org/

Union of EcoDesigners (Japan)

http://www.bcasj.or.jp/EcoDesign/

United Nations Centre for Human Settlements (Habitat)

http://www.unchs.org/

United Nations Commission on Sustainable Development

http://www.un.org/esa/sustdev/csd.htm

United Nations Development Programme (UNDP)

http://www.undp.org/

United Nations Framework Convention on Climate Change (UNFCCC)

http://www.unfccc.de/

Urban Ecology

http://www.urbanecology.org/

U.S. Green Building Council (USGBC)

http://www.usgbc.org/

The Used Building Materials Association (UBMA)

http://www.ubma.com/

WSU Cooperative Extension Energy Program

http://www.energy.wsu.edu

Wisconsin Green Building Alliance (WGBA)

http://www.wgba.org/

World Bank

http://www.worldbank.org/

WorldBuild

http://www.worldbuild.com/

World Business Council for Sustainable Development (WBCSD)

http://www.wbcsd.com/

The World Conservation Union (IUCN)

http://www.iucn.org/

World Resources Institute (WRI)

http://www.wri.org/

Worldwatch Institute

http://www.worldwatch.org/

Directories and Sites on Ecology, Environment and Sustainability

Alternative Architecture and Sustainable Development

http://apocalypse.org/pub/u/paul/arch.html

Architecture Web Resources

http://library.nevada.edu/arch/rsrce/webrsrce/main0018.html#Women2717

Best Environmental Directories

http://www.ulb.ac.be/ceese/meta/cds.html

Building Energy Efficiency Research (BEER)

http://arch.hku.hk/reserach/BEER

Campaign Interactive - European Sustainable Cities Project

http://www.sustainable-cities.org/

Commercial Building Incentive Program (CBIP) (Canada)

http://cbip.nrcan.gc.ca/cbip.htm

Ecosustainable

http://www.ecosustainable.com.au/links.htm

Energy in Architecture - Resources

http://arch.hku.hk/teaching/learn.htm - energy in architecture

Green Building Resource Center

http://www.greendesign.net/gbrc/index.html

Green Building Source

http://oikos.com/index.lasso

DOE Headquarters Library

http://vm1.hqadmin.doe.gov/library/

Ecogovernment

http://home.earthlink.net/~jluke313/government.html

Energy Smart Commercial Buildings Links

http://www.sea.vic.gov.au/building/ESCB/links.html

Environmental Design and Sustainability - Related Web Sites

http://www.arch.vt.edu/Sustainability/extras/website.htm

Environmental Design Library

http://www.lib.berkeley.edu/ENVI/GreenAll.html

European Housing Ecology Network (EHEN)

http://www.ehen-europe.net/

Global System for Sustainable Development (GSSD) [MIT]

http://gssd.mit.edu/

Green Buildings for Africa

http://www.greenbuildings.co.za/

Green Haus - Homes and Our Environment

http://home.earthlink.net/~dlombard/

Green Innovations

http://www.green-innovations.asn.au/

Green Office [UNSW]

http://www.emp.unsw.edu.au/GOP/Index.html

Greening the Games (Sydney Olympics)

http://www.sg.com.au/ea/body01.html

Greening Government - UK

http://www.environment.detr.gov.uk/greening/

GreenWork.TV

http://www.greenworks.tv/

Hybrid Ventilation in New and Retrofitted Office Buildings [IEA Annex 35]

http://hybvent.civil.auc.dk/

IEA-BCS Annex 31: Energy related environmental impact of buildings

http://www.uni-weimar.de/SCC/PRO/

The Integer Project (UK)

http://www.integerproject.co.uk/

Integrated Building Technology

http://arch.hku.hk/teaching

Jamaica Sustainable Development Networking Programme (JSDNP)

http://www.jsdnp.org.jm/Index.htm

Residential Environmental Design and Sustainable Architecture for Architects and Homeowners

http://www.reddawn.com/

Renewable Energy

http://arch.hku.hk/research/BEER/renew.htm

Renewable Energy Policy Project

http://solstice.crest.org/common/crestinfo.shtml

Smart Architecture

http://www.smartarch.nl/

Sustainable Architecture and Building Design

http://www1.arch.hku.hk/research/BEER/sustain.htm

Sustainable Architecture Resource List

http://www.umich.edu/~nppcpub/resources/ResLists/arch.html

Sustainable Building Resource

http://www.iris.ba.cnr.it/sustain/welcome.asp

Sustainable Home

http://www.sustainablehomes.co.uk/index.htm

Sustainability Forum at MIT Department of Architecture

http://destec.mit.edu/forum

The Sustainability Report

http://www.sustreport.org/

Sustainability Web Ring

http://sdgateway.net/webring/default.htm

Vision 2020 Los Alamos - Green Building

http://www.vision2020la.org/Green_Building/green_building.htm

Research Centers

Atmospheric Research & Information Centre, Manchester Metropolitan University

http://www.doc.mmu.ac.uk/aric/

Center for Energy Efficiency & Renewable Technologies (CEERT)

http://www.ceert.org/home.html

Centre of Environmental Philosophy, Planning and Design, University of Canberra

http://design2.canberra.edu.au/fed/fed/CentreEPPD.html

Center of Excellence for Sustainable Development (CESD), USDOE

http://www.sustainable.doe.gov/

Centre for Renewable Energy Systems Technology (CREST), University of Loughborough, UK

http://info.lboro.ac.uk/departments/el/research/crest/index.html

Center for Resourceful Building Technology (CRBT)

http://www.montana.com/crbt/

Centre for Studies in Urban Sustainability (CSUS), HKU

http://hkusury2.hku.hk/sustainable_urban_development/

Centre for Sustainable Technologies, University of Ulster

http://www.engj.ulst.ac.uk/SCOBE/CST/index.html

Center for Sustainable Urban Neighborhoods, University of Louisville

http://www.louisville.edu/org/sun/

Ecological Design Group (EDG), The Robert Gordon University, Aberdeen, Scotland

http://www.rgu.ac.uk/subj/ecoldes/edg1.htm

Edinburgh Sustainable Architecture Unit (ESAU)

http://www.caad.ed.ac.uk/units/ESAU/

Energy and Environment Research Unit (EERU), Open University, UK

http://eeru-www.open.ac.uk/

Environmental Energy Technologies Division

http://eetd.lbl.gov/

FICUS-Florida Internet Center for Understanding Sustainability

http://www.ficus.usf.edu/

IVAM Environmental Research (Netherlands)

http://www.ivambv.uva.nl/

MIT Building Technology Group

http://web.mit.edu/bt/www/

Pacific Energy Center

http://www.pge.com/003_save_energy/003c_edu_train/pec/
003c1_pac_energy.shtml

Sandia National Laboratories Renewable Energy Office

http://www.sandia.gov/Renewable_Energy/renewable.html

Sustainable Buildings for China [MIT]

http://btserver.mit.edu/china/index.html

Sustainability Research Profiles [Second Nature]

http://www.secondnature.org/programs/profiles.nsf

Simulation Research Group

http://gundog.lbl.gov/

United Nations Environment Programme

http://www.unep.org/

The Vital Signs Project

http://www.arch.ced.berkeley.edu/vitalsigns/

Appendix C - Journals and News

Architecture Week

http://www.architectureweek.com/topics/green.html

Architectural Record

http://www.archrecord.com/GREEN/GREEN.ASP

Architronic

http://architronic.saed.kent.edu/

Ecocycle

http://www.ec.gc.ca/ecocycle/english/default.htm

Environmental Building News

http://www.buildinggreen.com/

Environmental Design & Construction

http://www.edcmag.com/

FacilitiesNet

http://www.facilitiesnet.com/fn/

Building Operating Management

Bhttp://www.facilitiesnet.com/fn/bom

Energy Decisions

http://www.facilitiesnet.com/fn/energydecisions

Green Books

http://www.greenbooks.co.uk/

Green Building News [oikos]

http://oikos.com/

Residential Environmental Design and Sustainable Architecture

http://www.reddawn.com/

Terrain: A Journal of the Built & Natural Environments

http://www.terrain.org/

WinterGREEN Newsletter [Steven Winter Associates]

http://www.swinter.com/company/WinterGREEN.html

Appendix D – Green Building Guidelines and Programs

Guidelines

Greening Federal Facilities

http://www.eren.doe.gov/femp/greenfed/

Guiding Principles of Sustainable Design - US Park Services

http://www.nps.gov/dsc/dsgncnstr/gpsd/toc.html

High Performance Building Guidelines - Pennsylvania

http://www.gggc.state.pa.us/publictn/gbguides.html

Minnesota Sustainable Design Guide

http://www.sustainabledesignguide.umn.edu/

New York City Department of Design and Construction

http://www.ci.nyc.ny.us/html/ddc/html/pdfdl.html#guidelines

Process Guide for High Performance Buildings - Florida

http://sustainable.state.fl.us/fdi/edesign/resource/index.html

EPA & USGBC – Sustainable Building Technical Manual

http://www.sustainable.doe.gov/pdf/sbt.pdf

Greening Federal Facilities - Federal Agency Management Program

http://www.eren.doe.gov/femp/greenfed/

U.S. Postal Service – Building Design Standards

Sustainable Building Handbook - Hellmuth, Obata & Kassabaum, Inc.

http://www.hok.com/sustainabledesign/

United States Air Force Environmentally Responsible Facilities Guide

http://www.aett.gov.bc.ca/environmental/data/environt/sec-one.htm#sec-one

United States Air Force – Green Base of the Future

http://www.dexix.osd.mil/denix/Public/Library/Eprfguide/eprf1.html

United States Navy Whole Building Design Guide

http://www.wbdg.org/

Green City Programs

Alameda County Waste Authority

http://www.stopwaste.org/fsbuild.html

A Blueprint for Greening Affordable Housing

http://www.globalgreen.org/pdf/index.html

Build a Better Kitsap - Washington

http://www.wa.gov/kitsap/departments/pubworks/buildbetter.html

Cambridge Sustainable City

http://www.sustainablecity.net/

City of Austin Green Building Program

http://www.aett.gov.bc.ca/environmental/data/environt/sec-one.htm - sec-one

Denver, Colorado – Built Green

http://www.builtgreen.org/

Green City Project

http://www.green-city.org/

Green Design / Sustainable Architecture Information Sources [UC Berkeley]

http://www.lib.berkeley.edu/ENVI/GreenAll.html

Green Design Initiative (GDI)

http://www.ce.cmu.edu/GreenDesign/

The Green Engineer

http://www.greenengineer.com/index.shtml

Greenspiration!

http://www.greenspiration.org/

Hydroponics

http://www.hydroponicsonline.com/

Los Angeles, California - Green Building Guidelines

http://www.globalgreen.org/pdf/index.html

Oakland, California - How-to Design Guide for Green Buildings

Philadelphia, Pennsylvania – Save Energy Campaign

City of Portland, Oregon – Green Building Options
http://www.ci.portland.or.us/energy/greenbuilding.htm

Green Design Initiative (GDI)

http://www.ce.cmu.edu/GreenDesign/

San Francisco, California - Strategies for Resource Efficient Buildings

http://www.ci.sf.ca.us/90043.htm

San Jose, California - Local Guidelines & Incentives

Santa Monica Green Building Guidelines

http://greenbuildings.santa-monica.org/sitemap.htm

Scottsdale Green Building Program

http://www.ci.scottsdale.az.us/greenbuilding/RatingWS.aspGreen Design Initiative (GDI)

Seattle Sustainable Building

http://www.ci.seattle.wa.us/seattle/util/rescons/susbuild/default.htm

Seattle, Washington – Sustainable Building Action Plan

http://www.ci.seattle.wa.us/seattle/util/rescons/susbuild/default.htm

State & County Municipalities

Nebraska – Moving Toward Sustainability

Central New Mexico – Green Builder

Kitsap County – Build a Better Kitsap

http://www.wa.gov/kitsap/departments/pubworks/buildbetter.html

Suburban Maryland – Building Green

Florida - Process Guidelines for High Performance Buildings

http://sustainable.state.fl.us/fdi/edesign/resource/index.html

Oregon - Green Building Project

http://www.hcs.state.or.us/data_research/greenbuilding/index.html

Hennepin County, Minnesota - Sustainable Design Guide and Rating System

http://www.sustainabledesignguide.umn.edu/

Alameda County, California - Green Builder Guidelines

http://www.stopwaste.org/fsbuild.html

Environmental Performance Rating Systems

Breeam – UK
http://www.bre.co.uk/index.html

Breeam Office 1998 – Canada
http://www.breeamcanada.ca/

Bepac – British Columbia
http://www.bepac.dmu.ac.uk/index.html#What's_Here

British Columbia University – Facilities Branch Environmental Guidelines

http://www.aett.gov.bc.ca/environmental/data/environt/sec-one.htm#sec-one

U.S. Green Building Council – LEED

http://www.usgbc.org/

Eco-Quantum – Holland

Green Building Challenge 2000 – International partnership of 14 countries

Queen's University of Belfast's – Green Building Handbook

Appendix E – Sustainability Tools

Simulation Tools

Building Energy Software: Tools Directory

http://www.eren.doe.gov/buildings/tools_directory/

BE2AM: Building Energy and Environmental Assessment Method

http://www.ecde.demon.co.uk/be2am.htm

Environmental Support Solutions

http://www.environ.com/

EQUER (France)

http://www-cenerg.ensmp.fr/francais/batiment/15.html

International Association for Impact Assessments (IAIA)

http://www.iaia.org/

Global Environmental Options (GEO)

http://www.geonetwork.org/

Green Buildings [Center of Excellence for Sustainable Development]

http://www.sustainable.doe.gov/buildings/gbintro.htm

Computer based Tools

Green Buildings [Center of Excellence for Sustainable Development]

http://www.sustainable.doe.gov/buildings/gbintro.htm

Interactive Tools Survey [University of Weimar, Germany]

http://www.uni-weimar.de/SCC/PRO/TOOLS/inter.html

Building Energy Simulation Tools

http://www.inf.bauwesen.tu-muenchen.de/personen/christop/bsim/building_energy.htm - Energy%20Programs

Introduction to OTTV and Simulation Tools

http://arch.hku.hk/~cmhui/teach/65256-X.htm

Life Cycle Analysis and Costing

Activity-Based Management

http://www.emblemsvag.com/

ATHENA Sustainable Materials Institute

http://www.athenasmi.ca/

BEES (Building for Environmental and Economic Sustainability)

http://www.bfrl.nist.gov/oae/software/bees.html

Eco-Quantum (Netherlands)

http://www.ivambv.uva.nl/uk/producten/product7.htm

ENVEST (environmental impact estimating design software) [UK BRE]

http://products.bre.co.uk/envest/

LCAid (Australia)

http://www.projectweb.gov.com.au/dataweb/lcaid/

Life-Cycle Assessment

http://www.emblemsvag.com/LCA.htm

Buildings and Life-Cycle Costing [Canadian Building Digest]

http://www.nrc.ca/irc/cbd/cbd212e.html

Comparing the Environmental Effects of Building Systems [Canadian Wood Council]

http://www.cwc.ca/english/publications/technical_bulletins/tech_bull_4/

Life Cycle Analysis for Residential Buildings [Canadian Wood Council]

http://www.cwc.ca/english/publications/technical_bulletins/tech_bull_5/

Life-Cycle Costing

http://dept.lamar.edu/industrial/Graduate/..%5CClasses/..%5CUnderdown/eng_mana/Life_Cycle_Costing_Shtub_ch10.htm

Life Cycle Costing and Stainless Steel

http://www.assda.asn.au/lifecycle1.html

Life Cycle Costing Program-Version 2.0

http://www.assda.asn.au/lifecycle1.html

LISA (LCA in Sustainable Architecture)

http://www.lisa.au.com/

Design Tools

Energy Design Tools

http://www.aud.ucla.edu/energy-design-tools/

Building Design Advisor

http://kmp.lbl.gov/BDA/

Appendix F Green Campus Initiatives

Blueprint for a Green Campus

http://www.envirocitizen.org/cgv/blueprint/index.html

British Columbia University

http://www.aett.gov.bc.ca/environmental/data/environt/sec-one.htm

Brown in Green

http://www.brown.edu/Departments/Brown_Is_Green/

Building a Green Campus

http://www.uvm.edu/~jfrances/report.html

Carnegie Melon – Green Design Initiative

CSU, Monterey Bay – Greening of the Campus

http://kelp.monterey.edu/const/index.shtml

Duke University – Environmental Sustainability Program

Environmental Education and Campus Greening

http://www.lib.msu.edu/link/enved.htm

FGCU Green Building Project

http://www.fgcu.edu/greenbuilding/index.html

Florida A&M University – Guidelines & Principles for Sustainable Community Design

http://fcn.state.fl.us/fdi/index.html

Georgia Tech – Primer for Sustainable Design

Green Campus Design Saving 60% on Energy [CSIRO]

http://www.dbce.csiro.au/inno-web/0600/green_campus.htm

Green Campus Issues [Havard]

http://hcs.harvard.edu/~eac/greencampus.htm

Greening the Campus: Sustainability and Higher Education

http://www.islandpress.org/economics/energy/greencamp.html

Merced Campus – Principle Initiative

Middlebury College – Guiding Principles

"Pathways to a Green Campus" Report

http://www.middlebury.edu/~enviroc/content.html

Sustainability - Green Campus Initiatives

http://www.epa.gov/region01/steward/univ/sus.html

Sustainable Development on Campus [IISD]

http://iisd1.iisd.ca/educate/

Tufts University - Greening the Ivory Tower

University of Michigan, Sustainable Architecture

http://www.umich.edu/~nppcpub/resources/compendia/architecture.html

University of Washington – Facility Design Information Manual

http://depts.washington.edu/~fsesweb/fdi99/index.html

Appendix G – Architects and Consultants

Architects

Amacher & Associates

http://amacher.hypermart.net/index.htm

Amstein + Walthert AG

http://www.amstein-walthert.ch/

Andropogon

http://www.andropogon.com/

BEAR Architects

http://www.bear.nl/

Beckman Sustainable Architecture

http://www.nevada.edu/~beckman/

Bob Easton AIA Architects

http://www.bobeaston.com/

Busby & Associates Architects

http://www.busby.ca/

Bruce Coldham, Architect

http://www.coldhamarch.com/

Debra Lombard

http://home.earthlink.net/~dlombard/DEBRALOMBARD.htm

Dennis Holloway

http://www.taosnet.com/architectVRe/

Donald Reed Chandler Architect

http://www.coldhamarch.com/

EcoArch

http://ecoarch.com/

Ecological Design Institute

http://www.ecodesign.org/edi/index.html

Ecopolis

http://www.ecopolis.com.au/Eley Associates

Emilio Ambasz and Associates, Inc.

http://www.ambasz.com/

Emilis Prelgauskas

http://www.emilis.sa.on.net/

Enno Wiersma Architect, Urban & Interior designer.

http://www.stratosphere.org/

Entech Engineering HomePage

http://www.entecheng.com/

Environ Design Collaborative

http://www.cstone.net/edc/index1.htm

Eugene Tsui (Evolutionary Architecture)

http://www.tdrinc.com/

Future Systems

http://www.future-systems.com/

Green Architecture (Javier Barba Studio BC Architects and Urbanism, Spain)

http://www.greenarchitecture.com/

HDR Sustainable Design

http://www.hdrinc.com/Architecture/sustain/default.htm

Helio Dias da Silva

http://www.geocities.com/Athens/Acropolis/2758

HOK - Sustainable Design

http://www.hok.com/sustainabledesign/

Indiana Architecture

http://www.indiana-architecture.com/

Innovative Design

Innovative Design

Jersey Devil Design/Build

http://www.jerseydevildesignbuild.com/

Ken Yeang - Bioclimatic Skyscrapers

http://www.ellipsis.com/yeang/text.html

LiQWood Design Studios

http://www.liqwood-design.com/

Locus Architecture

http://www.locusarchitecture.com/

LOG ID (Dieter Schempp)

http://www.agsn.de/logid/

Marcus and Willers Architects

http://www.vom.com/mwa/mw3hp.htm

Micheal Rosenfeld Inc. Architects

http://www.omr-architects.com/sm/sustainable.html

MFP Australia

http://www.mfp.com.au/

Paul de Ruiter'

http://www.archined.nl/paulderuiter/

Peter Vetsch (Earth & Cave Architecture)

http://www.vetsch.ch/

Pfau Architecture

http://www.pfauarchitecture.com/indexf.html

Ray Bahm and Associates

http://www.rt66.com/rbahm/

Renzo Piano Workshop Foundation

http://www.rpwf.org/

Richard Rogers Partnership

http://www.richardrogers.co.uk/

Robert A. Armon Architect

http://www.sacredarch.com/

rkeytexDESIGN

rkeytexDESIGN

Solar Design Associates, Inc.(SDA)

http://www.solardesign.com/~sda/

Tsui Design & Research Inc.

http://www.tdrinc.com/

Van der Ryn Architects

http://www.vanderryn.com/

White & Gilbride Architects, Canada

http://white.on.ca/

William McDonough + Partners

http://www.mcdonough.com

Consultants

Biospaces

http://rof.net/yp/biospace/welcome.html

C o n s t r u c t i o n T e c h n o l o g i e s

http://members.home.net/lyfordg/

CSIRO Built Environment

http://www.dbce.csiro.au/ind-serv/brochures/suscon/suscon.htm

Design Advice (UK)

http://www.designadvice.co.uk/

Duluth Timber Company

http://www.duluthtimber.com/

ECD Energy and Environment (UK)

http://www.ecde.demon.co.uk/

Eco-Products

http://www.ecoproducts.com/

Enermodal Engineering Limit.

http://www.enermodal.com/

Enertia¨ Building Systems

http://enertia.com/

Environmental Support Solutions, Inc. (ESS)

http://www.environ.com/

Green Building Services

http://www.greenbuildingservices.com/

Hanna Shapira

http://www.public.usit.net/hshapira/

IRT Environment, Inc

http://solstice.crest.org/efficiency/irt/

PRe (Netherlands)

http://www.pre.nl/

Rezacheck & Associates

http://www.sustainablehawaii.com/

Robert Q. Riley Enterprises

http://www.netzone.com/~rqriley/

Roy F. Weston, Inc.

http://www.rfweston.com/

Siemens Solar Industries

http://www.solarpv.com/

SunStar of Arizona

http://www.azsunstar.com/

Sustainability.com

http://www.sustainability.com/

SustainAbility Ltd. (UK)

http://www.sustainability.co.uk/

Appendix H - Case Studies

901 Cherry in San Bruno, California

http://bacqube.bayareacouncil.org/901/

Adam J. Lewis Center for Environmental Studies

http://www.oberlin.edu/newserv/esc/

Audubon House: Building for an environmental future

http://www.audubon.org/nas/ah/index.html

Barney-Davis Green Renovation

http://www.denison.edu/enviro/barney/

Beddington Zero Energy Development (BedZED)

http://www.bedzed.org.uk/

BRE Environmental Building at Garston

http://projects.bre.co.uk/envbuild/index.html

Case Studies [Smart Growth Network]

http://www.smartgrowth.org/casestudies/casestudy_index.html

Case Studies at HKU Arch

http://arch.hku.hk/research/BEER/casestud.htm

Chattanooga Sustainability Page

http://new.chattanooga.net/sustain/

C. K. Choi Building, Institute of Asian Research, University of British Columbia, Canada

http://www.iar.ubc.ca/choibuilding/matsuzaki.html

Current Projects of Sustainable Urban Housing in China [MIT Building Technology]

http://chinahousing.mit.edu/english/projects/

Demonstration House I

http://greenhome.org/demo.htm

Demonstration House II

Demonstration House II

Department of Environmental Protection, Commonwealth of Pennsylvania Cambria Office

http://www.gggc.state.pa.us/building/Cambria/default.htm

ECO DESIGN Octagonal Yurt building

http://www.powerup.com.au/~edesign/yurtpage1.htm

Ecoschool

http://www.takenaka.co.jp/takenaka_e/school_e/sch03/03_4.html

enCompass - map of recycled-content buildings

http://dnr.metrokc.gov/market/encompass/index.htm

Environmentally Responsible Projects

http://www.takenaka.co.jp/takenaka_e/env_pro_e/index.htm

Green Buildings Success Stories [CESD]

http://www.sustainable.doe.gov/buildings/gbsstoc.htm

Green Development Case Studies [RMI]

http://www.rmi.org/sitepages/pid199.asp

GreenHome

http://greenhome.org/

HOK Sustainable Design - Case Studies

http://www.hok.com/sustainabledesign/casestudies/casestudies.html

Lady Bird Johnson Wildflower Center Complex, Austin Texas

http://www.wildflower.org/hq.html

NEXT 21 (Osaka Gas Experimental Housing)

http://arch.hku.hk/~cmhui/japan/next21/next21-index.html

Pennsylvania's First Green Building: DEP's Southcentral Regional Office Building

http://www.gggc.state.pa.us/building/scrob.html

RITE Head Office

http://arch.hku.hk/~cmhui/japan/rite/rite-index.html

Thoreau Center for Sustainability, San Francisco

http://www.thoreau.org/

Tokyo Gas Earthport

http://arch.hku.hk/~cmhui/japan/tokyo gas/gas-index.html

UNEP International Environmental Center

http://arch.hku.hk/~cmhui/japan/unep/unep-index.html

US Green Building Council - Green Building Case Studies

http://www.usgbc.org/resource/cs.htm

Village Homes: A model solar community proves its worth

http://context.org/ICLIB/IC35/Browning.htm

Vital Signs Case Studies

http://www.arch.ced.berkeley.edu/vitalsigns/

Zion Canyon Visitor and Transportation Center, NREL

http://www.nrel.gov/buildings/highperformance/projects/zion/zion.htm

Appendix I – Building Materials and Products

Building Envelope

Gas-Filled Panels (high performance insulation)

http://gfp.lbl.gov/default.htm

Transparent Insulation

http://www.ise.fhg.de/Projects/development99/art4.html

Building Innovation

Research Division of CMHC

http://www.cmhc-schl.gc.ca/rd-dr/en/icontent.html

Highrise & Multiples Innovation Group

http://www.cmhc-schl.gc.ca/rd-dr/en/icontent.html

Building Materials

Bill Lawson's Notes on Materials and Sustainability (UNSW)

http://www.fbe.unsw.edu.au/Learning/material-notes/

Building materials: what makes a product green? (Alex Wilson)

http://www.buildingreen.com/features/gp/green_products.html

casey and amber's Sustainable building materials home page

http://www.uark.edu/depts/dbertonc/CaseyandAmber/index:htm

EnCompass - Map of Recycled Content Buildings

http://dnr.metrokc.gov/market/encompass/index.htm

EcoMarket International

http://www.ecomarket.net/

Green Products Guide [Architectural Record]

http://www.archrecord.com/GREEN/GREEN.ASP

GoodCent.com

http://www.goodcents.com/

Green Building Databases & Design Resources http://www.greenbuilder.com/general/GreenDBs.html

The Green Culture

http://www.greenculture.com/

Green Shop

http://www.greenshop.co.uk/

Habitat Designs

http://habitatdesigns.com/sbmrg/csi/csistart.htm

Happy Harry's Used Building Materials

http://www.happyharry.com/

The Harris Directory of Pollution Prevention Products for Home, Office and Garden

http://www.harrisdirectory.com/

HOK's Healthy and Sustainable Building Materials Database

http://www.hok.com/sustainabledesign/database/welcome.html

Recycled Content Product Database [California Integrated Waste Management Board]

http://www.ciwmb.ca.gov/rcp/

Reusable Building Materials Exchange (RBME)

http://www.rbme.com/

Self-sustaining home products

http://www.longcayebelize.com/ecovillage/selfsustaining products.htm

Sustainable Facilities: Building Material Selection (West Michigan Sustainable Business Forum)

http://www.sustainable-busforum.org/bldgmat.html

Sustainable Architecture Building and Culture

http://www.sustainableabc.com/materials.html

Sustainable Materials Building Advisor

http://www.usc.edu/dept/architecture/mbs/tools/sbma/index.html

Sustainable Building Resource (Italy)

http://www.iris.ba.cnr.it/sustain/

Sustainable Design Resource Guide, AIA

http://www.diac.com/~ggray/SDRG/

Sustainable Development Resources database

http://www.ncat.org:7050/

Sustainable Home Guidelines [Waitakere City Council, New Zealand]

http://www.waitakere.govt.nz/ecocity/ecobuild/homeguide/default.htm

Concrete Reuse

Cement and Concrete: Environmental Considerations [EBN]

http://www.buildinggreen.com/features/cem/cementconc.html

Concrete Network

http://www.concretenetwork.com/concrete/countertops/index.html

Earth Architecture / Natural Buildings

Adobe Builder Magazine

http://www.adobebuilder.com/

Adobe Home Construction

http://www.epsea.org/adobe.html

CalEarth Forum

http://www.calearth.org/

Community Eco-Design Network (CEDN)

http://www.cedn.org/

The Earth Building Foundation, Inc.

http://www.earthbuilding.com/

EcoArch

http://home.earthlink.net/~jluke313/

Ecological Engineering and Sustainable Strategies

http://www.ecological-engineering.com/index.html

Ecosustainable Hub

http://www.ecosustainable.com.au/

Earthship

http://www.slip.net/%7eckent/earthship/

Earthship Architecture

http://www.earthship.org/home.htm

Earthship Internet Community

http://www.earthship.org/

Earthship Landing - Alternative Way of Building

http://www.alternative-way.com/

Earth Sheltered Homes by Davis Caves

http://www.daviscaves.com/

Earthfriendly and Self-Sufficient Architecture (ESSA)

http://csf.colorado.edu/lists/essa/

Earth House

http://earth-house.com/

Enertia Building Systems

http://enertia.com/default.htm

home sweet earth home

http://www.undergroundhomes.com/

The Natural Home Building Source

http://www.thenaturalhome.com/

Natural Spaces Domes

http://www.naturalspacesdomes.com/

Space on Earth (Earth-sheltered)

http://www.earth-sheltered.com/

Strawbale Construction

Addressing institutional barriers to straw bale construction

http://www.azstarnet.com/~dcat/barriers.htm

California Straw Building Association (CASBA) http://www.strawbuilding.org/

House of Straw - Straw Bale Construction Comes of Age [EREN]

http://www.eren.doe.gov/EE/strawhouse/

The Last Straw

http://www.strawhomes.com/

Natural Building Resources

http://www.strawbalecentral.com/

Strawbale Construction [21Design]

http://www.21design.com/prodinfo/strawbale/index.html

Straw Bale Home Construction

http://www.epsea.org/straw.html

Strawhomes.com

http://www.strawhomes.com/

Surfin' StrawBale Links List

http://mha-net.org/html/sblinks.htm

Natural Ventilation

Energy recovery possibilities in natural ventilation of office buildings

http://www.byggforsk.no/english/energy.htm

How Natural Ventilation Works

http://www.ae.iastate.edu/natural_ventilation.htm

Natural Ventilation

http://fridge.arch.uwa.edu.au/topics/thermal/airflow/ventilation.html

Natural ventilation system with heat recovery

http://www.caddet-ee.org/nl_html/994_07.htm

Natural Ventilation - A strategy for sustainability [MIT]

http://naturalvent.mit.edu/

Post-Occupancy Evaluation (POE) or Building Pathology

Post Occupancy Evaluation

http://ind4601-01.sp00.fsu.edu/POEabb/

Post-Occupancy Evaluation of Barney-Davis Hall

http://www.denison.edu/enviro/barney/poe.html

Post-Occupancy Evaluation of Higher Education Teaching Spaces - A Methodological Approach

http://www.scpm.salford.ac.uk/buhu/bizfruit/1998papers/dilanthi/dilanthi.htm

Post Occupancy Evaluation of San Francisco Public Library

http://sfpl.lib.ca.us/www/poe_executive_summary.html

The Power of POE

http://www.fdm.com/db_area/archives/1999/9906/poe.html

Solar Air-conditioning

IEA Task 25 Solar assisted cooling systems

http://fridge.arch.uwa.edu.au/topics/thermal/airflow/ventilation.html

Solar-powered air conditioning

http://www.thesrtgroup.com/prod03.htm

Solar powered LiBr chillers

http://www.suntherm.com/chillers.htm

SC1000-SolarCool DC Evaporative Cooler

http://www.longcayebelize.com/ecovillage/Solar Air Conditioning.htm

Vegetation

Greenroof.com

http://www.greenroofs.com/

Green Roofs for Healthy Cities

http://www.peck.ca/grhcc/main.htm

Roofscapes

http://www.roofmeadow.com/

SOPRANATURE (rooftop vegetation)

http://greenbuilding.ca/soprema/sop-main.htm

Waste Management (solid)

Canadian construction and demolition (C&D) waste

http://www.cdwaste.com/

Construction Waste Management Handbook

http://www.smartgrowth.org/library/constwastemgmt_hndbk.html

Factsheets [Waste Reduction Committee, HK]

http://www.info.gov.hk/wrc/main_factsheets.htm

Garbage and Recycling [Greater Vancouver Regional District]

http://www.gvrd.bc.ca/services/garbage/

International Waste Management Website

http://terrassa.pnl.gov:2080/fac/

OECD Work on Waste Management

http://www.oecd.org/ehs/waste/index.htm

Office of Waste Management, USDOE

http://www.em.doe.gov/em30/

Recycling Organic Waste: A Win-Win Proposition

http://www.worldwatch.org/alerts/pr970802.html

Urban Agriculture Notes by City Farmer

http://www.cityfarmer.org/

Solid Waste Management [CIVCAL at HKU]

http://civcal.media.hku.hk/solidwaste/default.htm

Water Conservation

Composting Toilets

Biolet

http://www.biolet.com/

The Compost Toilet & Greywater Recycling Systems Manual

http://www.powerup.com.au/~edesign/navbar.htm

The Humanure Handbook

http://www.weblife.org/humanure/

The World of Composting Toilets

http://www.compostingtoilet.org/

Clivus Multrum

http://www.clivus.com/

"Phoenix" Composting Toilet

http://www.compostingtoilet.com/

Sun Mar Composting Toilet

http://www.sun-mar.com/

Nature-Loo

http://www.nature-loo.com.au/

Rota-Loo

http://www.environq.com.au/

VERA Composters

http://www.vera.no/PG/start_frameset.html

VERA/Eco-Tech Carousel

http://www.ecological-engineering.com/

Drainwater Heat Recovery

Drainwater Heat Recovery (DHR) System - Gravity Film Exchange (GFX)

http://oikos.com/gfx/

GFX Drainwater Heat Recovery

http://www.eren.doe.gov/buildings/emergingtech/printable/page2d.html

Greywater Treatment

Greywater irrigation - grey waste treatment

http://www.greywater.com/

Living Technologies

http://www.livingmachines.com/

Oasis Design

http://www.oasisdesign.net/

On-Site Wastewater Treatment Systems [Green Center]

http://www.fuzzylu.com/greencenter/tb/tb006.htm

Water Conservation [CMHC-SCHL]

http://www.cmhc-schl.gc.ca/rd-dr/en/water-eau/index.html

Waterless urinals

http://www.waterless.com/

WaterWiser

http://www.waterwiser.org/

Water on the Space Station

http://science.nasa.gov/headlines/y2000/ast02nov%5F1.htm

Strategy	Minnesota Sustainable Design Guide	Univ. of Michigan Sustainable Building Technical Manual	New York City High Performance Building Guidelines	BREEAM	LEED 2.0	HOK Sustain-able Design Guide
Site						
Understanding the Site						
Direct development to environmentally appropriate areas - protect greenfields, encourage brownfield development	x			x	x	x
Site selection - maintain and enhance the biodiversity and ecology of the site, consider building footprint to minimize the impact on natural resources	x	x	x	x	x	x
Use microclimate and environmentally responsive site design strategies - preserve natural contours of site, understand the impact of design on nature by a comprehensive site analysis	x	x	x			x
Do not disturb the water table		x				
Schedule construction to minimize site impact		x				x
Erosion and sedimentation control					x	x
Building-Site Relationship						
General site layout - consider issues of building mass, orientation, outdoor spaces, passive principles, sun and shade patterns, landscaping			x			x
Improved environmental quality - coordinate landscape with building envelope design			x			
Mitigation of negative impacts - reduce heat island effect, avoid adverse impacts on adjacent properties, avoid light pollution	x		x		x	
Site lighting - use solar power, efficient lighting, reflective surfaces			x			

Strategy	Minnesota Sustainable Design Guide	Univ. of Michigan Sustainable Building Technical Manual	New York City High Performance Building Guidelines	BREEAM	LEED 2.0	HOK Sustain-able Design Guide
Sustainable Landscape Practice						
Planting practices - use native trees, shrubs and plants, avoid allergy-causing plants near bldg. intakes, avoid invasive species, reduce dependence on fertilizer, consider drip irrigation systems	x		x			
Water use/pollution prevention - provide porous surfaces for run-off drainage, filter stormwater through plantings and soil, harvest rainwater, do not use chemical pesticides			x		x	x
Soil quality - provide facilities for composting of landscape materials, use mulch to conserve soil moisture, allow clippings and leaves to decompose on the ground			x			x
Consider species diversity, wildlife habitat, and companion planting in plant selection						x
Consider transplanting trees and other vegetation						x
Stockpile and reuse soil and rock material						x
Evaluate the possibility of eliminating permanent irrigation by planting native vegetation						x
Minimize urban heat island effect through the use of light colored reflective materials						x
Resource use - use recycled, renewable and locally available materials for landscape features			x			
Provide adequate bicycle amenities	x	x	x			x
Promote use of public transportation - include bus stop seating areas	x	x	x		x	x
Provide alternative fueling facilities	x		x			x
Carpool incentives	x		x			x
Create pedestrian pockets		x			x	x

Water						
Minimize the Use of Domestic Water						
Ozonation - consider ozonation in commercial laundering, and condenser water systems			x			x
Fixture and fitting selection - use low-water or waterless fixtures, automatic shut-off controls, and metered faucets, consider the use of biocomposting toilets	x	x	x	x	x	x
Water Quality						
Standards - specify plumbing components that meet minimum standards			x			
Water sampling - water quality should be within EPA maximum contaminant levels and action levels			x			x
Filtration devices at point of entry and/or use - Consider installation of filters at taps and/or at the service lines			x			
Drinking water - use filtered tap water for drinking instead of bottled			x			
Water Reuse						
Use biological waste treatment systems - to reduce the volume of blackwater entering the municipal system	x				x	
Green roofs - plant roof areas to reduce the discharge of stormwater and to reap the benefits of increased green space			x			
Site retainage of rainwater - reduce rainwater runoff from the site, roofs, and building surfaces to minimize stress on sewer system and to divert and reduce water pollution	x	x	x		x	x
Irrigation and specialty use water - use systems that maximize efficient use of pressurized water and use high efficiency irrigation technologies	x				x	
Rainwater use - collect and use rainwater		x	x	x	x	x
Graywater use - collect and use graywater for water closets and urinal flushing	x	x	x		x	x
Excess groundwater - recover excess groundwater from sump pumps for use as a source of recycled water			x		x	

Strategy	Minnesota Sustainable Design Guide	Univ. of Michigan Sustainable Building Technical Manual	New York City High Performance Building Guidelines	BREEAM	LEED 2.0	HOK Sustain-able Design Guide
Steam condensate - collect and use utility district steam system condensate for non-potable uses			x			
Vacuum-assist systems - consider a 'vacuum-assist' system for flushing of water closets and urinals		x	x			
Water Conservation						
Conserve Cooling Tower Water Consumption	x					
Select chillers based on water conservation criteria; avoid one pass systems						x
Use efficient water heating and recirculation systems to conserve water						x
Work with natural drainage systems; supplement with detention/retention ponds and/or filtration systems when necessary						x
Indigenous landscaping		x			x	x
Water efficient landscaping - limit or eliminate the use of potable water for landscape irrigation.					x	
M a t e r i a l s						
Raw Material Extraction						
Use salvaged and remanufactured materials	x				x	x
Use recycled content products and materials	x		x	x	x	x
Use materials that are harvested or extracted without ecological damage		x				
Use materials that are made of certified sustatinable and renewable resources	x	x	x	x	x	x
Distribution						
Use materials with low environmental impact during their life cycle - conduct a life-cycle analysis	x		x			x
Use locally manufactured materials	x	x	x		x	x

Design						
Material conserving design and construction - design for adaptability and disassembly	x	x				x
Size buildings and systems efficiently		x				
Dimension materials carefully to minimize waste						x
Design and detail efficiently to reduce waste generation			x			
Use materials that are long-lasting and low maintenance	x	x	x			x
Reuse the land and existing infrastructure		x				
Use of Non-conventional Building Materials		x				
Eliminate unnecessary finishes			x			x
Consider life cycle costs of products		x	x			x
Design for storage & collection of recyclable				x	x	
Installation						
Use low VOC-emitting materials	x		x	x		x
Use materials that contain no CFC's, HCFC's, or halons			x			
Use of Reclaimed or Recycled Materials and Components		x				
Eventual Reuse or Waste						
Reuse and recycle building components and materials		x			x	
Reuse and rehabilitate existing structures		x			x	
Use materials that are reusable, recyclable or biodegradable	x	x	x			x
Energy						
Use Energy Sources with Low Env. Impact						
Renewable energy resources - consider the use of building-integrated photovoltaic panels, daylighting, active and passive solar collection systems	x		x		x	
Super-efficient, hybrid and emerging technologies - consider the use of geothermal heat pump, fuel cell, and heat recovery systems	x		x		x	
Site and Massing Considerations						
Solar access - orient the building to maximize solar opportunities and minimize unwanted solar heat gain	x	x	x			
Prevailing winds - orient the building to minimize thermal loss due to infiltration and maximize opportunity for natural ventilation	x		x			

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Tree location - locate so that deciduous trees block summer sun and evergreens block winter wind			x			
Topographical modifications - consider earth forms, berming to optimize thermal mass and/or insulation	x		x			
Interior Layout/Spatial Design						
Program zoning - group similar program functions in order to concentrate similar heating/cooling demands and simplify HVAC zoning loads			x			
Use passive zoning design as buffers			x			
Layout for natural systems - configure occupied spaces to optimize natural ventilation and daylighting			x			
Stairs - provide inviting staircases to encourage the use of stairs rather than elevators in low-rise buildings			x			
Building Envelope						
Use passive solar design strategies		x	x			x
Design for natural ventilation		x	x			x
Envelope detailing - avoid thermal bridging, detail the material assembly with best vapor barrier practices	x	x	x			
Reduction of convective heat losses from unplanned air flows - reduce unwanted stack effect, plan air pressure relationships between rooms as necessary		x	x			
Radiant cooling - for internally loaded buildings			x			
Use of low-embodied energy materials		x				x
Daylighting/Sun Control						
Glazing - specify glazing with high visible transmittance and integrate placement to avoid glare			x			x
Consider the design and use of monitors, clerestories, photocell-dimming sensors, light shelves, courtyards and atriums and fiber-optics to encourage daylight into the space			x			

Provide daylighting integrated with electric lighting controls	x					x
Light Pollution						
Reduced night lighting needs - limit lighting to zones where it is necessary for safe passage to entry and exit areas, control by timers and motion sensors			x			
Proper cut-off angles - use outdoor lighting fixtures with cut-off angles that prevent light from shining upward or too far beyond the intended area of illumination			x			
High Performance Lighting						
Lighting power density - design for efficient light source distribution low ambient lighting levels with task lighting fixtures that provide significant illumination of ceilings and walls			x			
Use high efficiency lamps and liminaires with electronic ballasts, efficiency-based controls, and lumen maintenance controls			x			x
Fixture uniformity - install lower wattage lamps with more frequency			x			
Electrical Systems and Equipment						
Equipment specification - specify energy efficient equipment, such as those with Energy Star Labels, and use of lcd computer displays screens			x			
Distortion minimization - use harmonic filters to minimize the distortion effects of non-linear loads			x			
Efficient motors - consider premium efficiency motors, controls and variable frequency drives			x			
Direct current utilization - use direct current from photovoltaic systems, fuel cells when applicable			x			
Avoid electromagnetic pollution/exposure - install electromagnetic field shielding			x			
Videoconferencing - design for the use of videoconferencing to avoid unnecessary travel			x			

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Mechanical Systems						
Performance improvement - determine overall environmental impact of building energy consumption, maximize mechanical systems performance	x		x			
Systems integration - consider all programmatic and architectural features when sizing HVAC units			x			
Zoning - use separate HVAC systems to serve areas with different hours of occupancy, perimeter vs. interior spaces, special occupancies, and spaces with different exposures			x			
Natural ventilation - consider natural vs. mechanical ventilation during swing seasons			x			
Distribution systems - analyze the benefits of variable air volume systems			x			
Gas heater/chiller - consider the use of a combination gas heater/chiller			x			
Distributed mechanical rooms - consider independent mechanical rooms on each floor to reduce ductwork and enhance the balance of delivered air			x			
Consider the use of heat recovery systems -			x			x
Partial load conditions - select high efficiency equipment that operates at high efficiencies under both full and partial load conditions			x			
Modular boilers - consider installation of multiple modular boilers that allow more efficient partial-load systems operation			x			
Do not use CFC/HCFC refrigerants			x	x	x	x
Consider the use of condensing boilers			x			

Chiller sizing - evaluate various sizes and models of chillers to identify units that will most efficiently meet demand requirements; avoid oversizing of cooling and heating equipment which can reduce efficiency			x			x
Dessicant dehumidification - consider dessicant dehumidification as an alternative to the conventional practice of overcooling outside air to remove latent heat prior to removal of sensible heat			x			
Energy management system - use independent advanced control system or for all building controls			x			
Maximize efficiency of electric power and distribution, and service water heating						x
Monitoring and controls - use controls that optimize system response to building pickup and download, energy consumption monitoring using hourly graphs, load shedding and peak electric demand reduction through scheduled equipment cycling, local controllers capable of independently managing equipment operation and gathering data for reporting			x			
Selection of control method components - use a building automation system to improve the efficiency of HVAC system			x			x
Systems integration - assess the interactions between the HVAC equipment and other related systems, such as lighting, office equipment, etc.	x		x			
Computerized control system - use a computerized control system to establish, maintain and document building climate conditions with a backup system in place			x			
Heating equipment - when reviewing options for boilers, consider oxygen trim controls, draft control inducers, demand control based on variations in heating demand, water reset control keyed to outside air temperature, burner flame control			x			

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Air conditioners, chillers, and ventilation controls						
Generate energy consumption profiles that identify occurrences of peak loads and develop responsive management strategies for reducing utility bills			x			
Set up the HVAC building control system to operate based on need, if multiple sources are available, minimize simultaneous heating and cooling, and supply thermal conditioning from the most appropriate/efficient sources			x			
Limit electrical demand during peak hours by turning off non-essential equipment			x			
Establish temperature and humidity setpoints based on occupancy patterns, scheduling and outside climate and seasonal condition			x			
Consider CO2 and VOC sensors to reduce outside air ventilation in large spaces with variable occupancy			x			
Provide sensors that are capable of adjusting the ventilation rate based on the number of people present in a room			x			
Provide adaptive, programmable thermostats capable of automatically adjusting settings based on recorded demand patterns			x			
Set supply air-temperature reset controls for variable air volume systems based on space occupancy			x			

Control strategies for chilled water plant - chiller speed control through variable speed drive controllers, selection of modular chillers or chillers with multiple compressors and chilled water reset, condenser water reset, chiller sequencing, soft-starting of chiller motor, demand control, use of two-speed motors or multiple units for pumps/fans, use of variable speed controllers for fans and pump motors			x			
Design Efficient Systems						
Use of energy-efficient appliances with timing devices	x	x				
Best practice commissioning - verify and ensure the entire building is designed, constructed, and calibrated to operate as intended with third party quality control assurance						x
Optimize energy performance - achieve increasing levels of energy performance above the prerequisite standard to reduce environmental impact associated with excessive energy use					x	x
Reduce carbon dioxide production due to energy consumption				x		
Measurement and verification - provide for the ongoing accountability and optimization of building energy and indoor environmental quality (IEQ) performance over time					x	x
Indoor Environment						
Indoor Air Quality						
Provide a Clean and Healthy Environment - Provide an environment for occupants that is physiologically and psychologically healthy.	x					
Provide ample ventilation for pollutant control and thermal comfort - minimize production and transmission of air pollution.	x					x
Minimum IAQ performance - establish minimum IAQ performance to prevent the development of indoor air quality problems in buildings, maintaining the health and well being of the occupants					x	

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Employ setbacks and landscaping buffers to protect openings from vehicle pollution; avoid the use of sporulating plants						x
Carbon dioxide (CO2) monitoring - provide capacity for indoor air quality (IAQ) monitoring to sustain long term occupant health and comfort					x	
Human Comfort						
Provide Appropriate Thermal Conditions - Provide needed operational control of systems to occupants.	x				x	
Provide Effective Lighting	x					
Provide Appropriate Building Acoustical and Vibration Conditions - Provide the full range of supportive sensory conditions (olfactory, thermal, vibracoustic, tactual and visual) for occupants.	x	x				
Provide views, Viewspace, and Connection to Natural Environment	x				x	
Accommodate Persons with Differing Physical Abilities		x				
Source control						
Source control - evaluate sources of contamination from neighboring buildings and soil contamination such as radon, methane and excessive dampness			x		x	
Locate and design air intakes to optimize air supply sources for the ventilation system, isolate building air intakes from building exhaust air, vehicular exhaust, cooling tower spray, combustion gases, sanitary vents, trash storage, and other hazardous air contaminants			x		x	x
Reduce potential pollution sources through effective moisture control			x			

Specify materials with low VOC's and low particulate and odor emissions			x			x
To avoid occupant exposure to airborne pollutants, perform cleaning and pest control activities when the building is largely unoccupied			x			
Ventilation						
Develop ventilation strategies that support operable windows, where appropriate to the site and function	x		x			
To avoid stagnant air in occupied spaces, design for at least 0.8-1.0 c.f.m./s.f. air movement	x		x		x	
Isolate potential pollution sources through separate zoning of areas where contaminants are generated			x			
Construction IAQ management plan - prevent indoor air quality problems resulting from the construction/renovation process, to sustain long term tradesman and occupant health and comfort					x	
Indoor chemical and pollutant source control - avoid exposure of building occupants to potentially hazardous chemicals that adversely impact air quality.					x	
Design mechanical systems that can provide and maintain the required ventilation rate, design ventilation system for high air change effectiveness, avoid short-circuiting supply air to return registers	x		x		x	
Specify ventilation systems that feature an economizer cycle, design and control HVAC economizers so as to prevent moisture problems			x			
Consider supplying ventilation air primarily to occupied zones using distribution systems such as underfloor air ducting			x		x	
Use rainproof louvers and limit intake air velocities to discourage water intrusion			x			
To prevent wetting downstream surfaces, select proper air velocities through cooling coils and humidifiers			x			

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Provide filtration capable of 60% or greater dust spot efficiency, installed to intercept all make-up and return air			x			
Consider use of low pressure drop, high efficiency air filters			x			
Avoid the use of fibrous duct liners and loose mineral fiber for internal ductwork insulation; use non-porous duct liners, external thermal insulation, or acoustical baffles in lieu of linings in strategic locations			x			x
Prevent condensation of water vapor inside the building envelope by proper use of moisture barriers, appropriate locations and amounts of thermal insulation, control of indoor-to-outdoor pressure differences, and control of indoor humidity			x			x
Commission the ventilation system to assure that design conditions are met, proper air deliver occurs in each zone, and optimum performance is achieved under full and partial load conditions			x			
Isolate potential pollution sources through separate zoning of areas generating contaminants			x			
Vent kitchens, toilet rooms, smoking lounges, custodial closets, cleaning chemical storage and mixing areas, and dedicated copying areas to the outdoors, with no recirculation through the HVAC system			x			
Avoid use of ozone-generating devices to clean or purify indoor air			x			
Control Systems						
Sensors for relative humidity, temperature, and carbon dioxide should be installed as close as possible to where occupants are located			x			

Locate sensors to cover areas of similar load conditions			x			
When demand control ventilation systems are used, ensure that carbon dioxide sensors are operating in a reliable manner			x			
Periodically audit all computer-controlled HVAC systems			x			
Specify controls on variable air volume systems to ensure that the amount of outdoor air delivered to the occupants is maintained, even when the total air supply is decreased			x			
In VAV systems, special controls may be needed to ensure that minimum outside air intake into the air handling unit is achieved during all operating conditions			x			
In VAV systems, at minimum, install temperature sensors in return air sections of air handling units to maintain air temperature at acceptable levels			x			
Construction Methods/Precautions						
Prevent storage of soft products on site during wet processes, unless separated and sealed			x			
Schedule installation of wet materials (sealant, caulking, adhesives) and allow them to dry or cure before installing dry materials that could serve as sinks and absorbents of VOC's			x			x
Ensure that construction materials such as concrete are dry before they are covered (with carpet or floor tile) or enclosed in wall cavities			x			x
Ensure that the contractor uses metal ductwork instead of substituting fiberglass			x			
Control fiber or particle release during installation of insulation and require general area cleanup prior to building occupancy			x			
Flush the building with 100% outside air for a period of not less than 30 days beginning as soon as systems are operable and continuing throughout installation of furniture, fittings, and equipment			x			

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Occupant Activity Control						
Maintain a no-smoking policy					x	x
Designate an Indoor Air Quality manager who receives ongoing IAQ training					x	
Provide Operable Windows		x	x			
Simplification - provide building users and maintenance staff with a level of control over automated building systems that is appropriate to their level of technical expertise			x			
Personal control - build in a capacity for personal control over the immediate indoor environment, assure that the global indoor environment is within acceptable limits by bringing air supply points and controls for air quality as close to individual workstations as possible; balance control system advantages against energy use and maintainability			x		x	
Light Sources						
Daylighting apertures - maximize daylighting through appropriate location and sizing of windows, roof monitors, and skylights, and through use of glazing systems and shading devices appropriate to orientation and space use			x		x	
Light shelves, surface reflectance - extend window light throw through the use of light shelves, prismatic glazing or louvers and through appropriate room surface reflectance and colors			x			
Light distribution - where appropriate, encourage use of relatively low general lighting levels and of predominantly reflected light, mainly from the ceiling			x			

Avoiding glare - Avoid arrangements of light sources and reflecting surfaces that cause direct or indirect glare and veiling reflections of light sources in visual task areas; avoid overlighting of spaces, use of deep window recesses, low partitions and strategically located high-reflectance surfaces			x			
Light levels - achieve a good balance between uniform light levels and localized variations to create a dynamic and comfortable visual environment; consider low-level ambient lighting augmented by high quality, flexible task lighting, varied lighting schemes that respond to general building organization and special features, allowing the lighting patterns to reflect changing activity scenarios during the working day			x			
Luminaire arrangements - arrange luminaires in types and patterns that clearly respond to the fundamental building organization, floor layout and entry paths of daylight while allowing for flexibility of space usage, wherever possible, wire luminaires in parallel to the walls with windows so they can be dimmed or turned off row by row			x			
Diffusers - select diffusers that reduce glare and sufficiently illuminate ceilings and walls to create a visual field similar to prevailing daylight conditions			x			
Color - provide lamps with high color rendering index, such as tri-phosphor fluorescent lamps			x			
Ballasts - use high frequency electronic ballasts to minimize flicker as lamps and ballasts wear			x			
Views - design a building organization and floor layout that gives each occupant adequate visual access to the outdoors and to the general organization of the building		x	x			
Window cleaning - schedule regular window cleaning to maximize the amount of daylight entering, particularly where windows are close to sources of air-borne dust, fumes or gases that reduce the transmission of light			x			

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Low-energy lighting - to minimize CO2 emissions arising from energy used for artificial lighting					x	
Daylighting - to improve the level of visual comfort produced by the lighting					x	
Noise Control			x			
Control noise at the source - site, orient and lay out the building such that external noise sources can be attenuated by distance of by topographic features or walls			x			
Attenuate Noise Along the Path of Transmission						
Place acoustic buffers, such as corridors, lobbies, stairwells, electrical/janitorial closets, and storage rooms, between noise-producing and noise-sensitive spaces			x			
Prevent transmission of sound through the building structure through use of floating floor slabs and sound-insulated penetrations of walls, floors, and ceilings			x			
Prevent transmission between exterior and interior by ensuring appropriate fabrication and assembly of walls, windows roofs, ground floor and foundations			x			
Prevent transmission between rooms by wall, floor, and ceiling assemblies by specifying materials with appropriate sound transmission class ratings, consider using set-off studs with sound-attenuating insulation, floating floor slabs and sound-absorbent ceiling systems			x			
Situate mechanical room doors across from non-critical building areas, consider the use of sound-rated acoustic doors and acoustic seals around these doors			x			
Avoid locating outside air intake or exhaust air discharge openings near windows, doors, or vents where noise can re-enter the building			x			

Consider wrapping or enclosing rectangular ducts with sound isolation materials			x			
Consider the use of sound attenuators and acoustic plenums to reduce noise in ductwork			x			
Noise Control in the Space Itself						
Absorb or block excessive background noise or interfering single-source sounds in open office environments through use of resilient flooring, ceiling and sound absorbing or reflecting partitions and furniture			x			
If appropriate conversational privacy cannot be achieved, consider using white noise			x			
In an open plan office space, offset workstations so that co-workers are not in direct line of sight or sound isolation and reduce sound reflection, install partial-height freestanding walls between workstations or work groups			x			
Achieve favorable room acoustics by configuring room geometry, positioning furnishings and furniture, and specifying appropriate surfaces			x			
Waste & PollutIon						
Conserving Resources						
Reuse existing buildings	x	x			x	x
Design for less material use - use modular dimensioning, and design for minimum square footage	x					x
Specify reuse of on-site materials to the greatest extend possible						x
Design building for adaptability - consider issues of site planning, structural systems, standardization or repetition of building elements, cladding systems, floor heights, raised floor systems, modular interior planning	x					
Design building for disassembly - consider issues of structural systems, cladding systems, materials, durability, snap release components, modular systems	x					

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Waste Management						
Salvage and recycle demolition waste	x		x		x	x
Recycle construction waste	x		x		x	x
Reduce and recycle packaging waste	x		x			x
Reduce and properly dispose of hazardous materials waste	x		x			x
Provide waste-separation facilities for building users	x	x	x		x	x
Provide waste-separation facilities for hazardous materials			x			x
Educate workers and occupants on recycling, waste reduction and prevention			x			

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