BridgeGreen
Bridging the Disconnect Between Design Professionals and Resources for Environmentally, Socially, and Economically Responsive Architecture

by

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Meredith Sue Elbaum

Submitted to the Department of Architecture on May 22, 2003, in partial fulfillment of the requirements for the degree of master of science in architecture studies

Abstract

Sustainable design, whether referred to as green, high performing, responsible, or environmentally, socially, and economically responsive architecture, is influencing the global building industry. Most major firms of architecture including Gensler, Hellmuth, Obata, Kassabaum, and Skidmore Owings and Merrill, are designing green buildings. Growth in programs like Leadership in Energy and Environmental Design (LEED) and Building Research Establishment Environmental Assessment Method (BREEAM), the United States and Great Britain's respective green building rating programs, illustrate the rising trend to go "green" within the industry. There are many obstacles facing the growth of the green building industry. While most architects admit green architecture is non-dismissible, because of these obstacles, they continue to design a majority of buildings with little consideration for environmental impact. Many of these obstacles can be overcome with the right resources.

Resources already exist to assist designers in lessening the environmental impact of buildings. However, there is a clear disconnect between available resources and the design professionals they target. Professionals, for the most part, do not know what these tools are, where to find them, who should use them, and when to use them in the design process. This thesis bridges this disconnect between design professionals and available resources. It suggests appropriate strategies for a prescribed design phase based upon environmental impact, building system, and design professional, and presents a list of resources for each strategy. Its aim is to disseminate resources to the appropriate professionals so that they can make informed decisions during the design process relative to environmental impact. Manifested in the form of an interactive web-based tool, it lends itself to future development. An increase in informed decisions will inevitably decrease the negative impact buildings have on the environment.

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1.0 Background

MIT Professor John Ochsendorf has conducted research on a bridge built over five hundred years ago in Peru, during the height of the Inca Empire. To this day, the bridge, incredibly, continues to carry people across the gorge of the Rio Apurimac. The bridge is the embodiment of sustainability. It is environmentally, socially, and economically responsive. Made of grass – a rapidly renewable, biodegradable, non-toxic material – and produced on current solar income, the Incan bridge has little impact on the environment. In addition, it fosters relationships between neighbors. Each year, the communities on either side of the gorge participate in a festival to rebuild the bridge. Women twirl grass together and men braid the strands to form long, thick ropes. When completed, the bridge unites the two communities and enables commerce between them, contributing to the communities' economic strength.

This thesis identifies that there is a disconnect between design professionals and resources for environmentally, socially, and economically responsive architecture. It illustrates a need for this genre of architecture, sometimes called sustainable design, and shows how it is distinct from the earlier environmental movement of the 1960s and 1970s. This thesis depicts how sustainability is influencing the global building industry and gaining acceptance among most major architecture and engineering firms. It also shows that while most architects and engineers admit green architecture is non-dismissible, the majority of them continue to design buildings with little thought to their ecological footprints and fail to use resources that could aid in their decision-making process. This thesis proposes BridgeGreen, an interactive Web-base tool, to bridge the disconnect. It is based upon and strives towards the same principles as the Incan bridge.

1.1 A Need for Environmentally, Socially, and Economically Responsive Architecture

There is a distinct need for environmentally, socially, and economically responsive architecture based upon the current state of the global environment and the impact humans and their buildings have on it.

1.1.1 The Global Environment

Every year, in developing countries, one million people die from urban air pollution, and twice that number die from exposure to smoke inside their homes. Another three million die prematurely from water-related diseases. Human activity threatens 32 percent of U.S. plants and animals with extinction (Building Green, 2003). More than half of the wetlands in the lower 48 states were lost between the late 1700s and the mid-1980s (Building Green, 2003). Sustainability advocates typically illustrate human impact on the environment by showing a rise in carbon dioxide levels and increase of world mean temperature since industrialization. (See Figures 1.1-1 and 1.1-2.) While the data is debatable, there is significant evidence pointing to human impact on the environment. For the purpose of this thesis, I take this primary issue as given. The debate, then, is how to live as part of nature without destroying it and, ultimately, ourselves. The World Bank's Vice President, Ian Johnson, gives us a clue when he states, "...tackling the underlying environmental causes of health problems will do a lot more good than just more hospitals and drugs (Economist, 2002)".

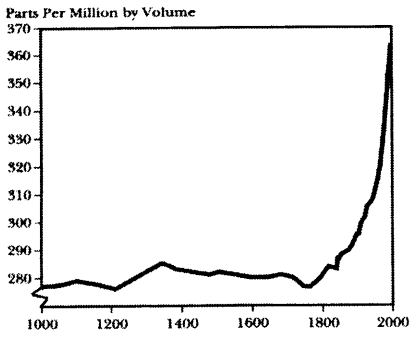


Figure 1.1—1 Atmospheric Concentrations of Carbon Dioxide 1000 – 1997 (Worldwatch Institute)

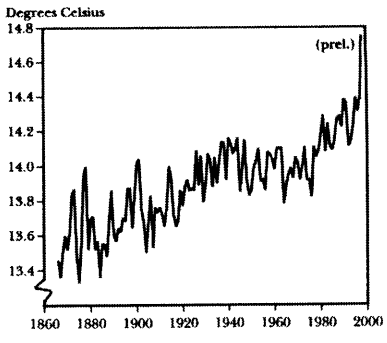


Figure 1.1—1 World Mean Temperature 1866 – 1998 (Worldwatch Institute)

1.1.2 Buildings' Environmental Impact

Building design professionals can play a significant role in reducing human impact on the environmental and causes of health problems. Proportionally, the building industry's contribution to environmental demise is substantial. Buildings contribute from 15 to 45 percent of the total environmental burden for each of the eight major Life Cycle Assessment inventory categories. (See Figure 1.1-3.) Buildings consume a substantial amount of energy in production as well as operation. One-third of America's total energy and two-thirds of its electricity is attributed to buildings (Hawken, 1999). In 1990, American households consumed $110 billion worth of energy. In fact, the highest energy "guzzlers" are not automobiles, but residences. About half of the word's total fossil fuel consumption is attributed to buildings (Barnett, 1998). In addition, the building industry consumes significant amounts of raw materials. Three billion tons of raw materials are used annually to construct buildings globally. The construction industry consumes one quarter of all the wood harvested. Buildings also contribute greatly to global warming and air pollutants. In 1999, 36 percent of United States carbon dioxide emissions were associated with residential and commercial sector energy consumption (U.S. DOE, 1999). Thirty percent of total U.S. greenhouse gas emissions, in 1999, were associated with residential and commercial sector energy consumption (U.S. DOE, 1999.) Roughly half of chlorofluorocarbon production is attributed to buildings in the form of refrigeration, air-conditioning, fire extinguishers, and insulation (Barnett, 1998). The manufacturing of Portland cement, used in most concrete, contributes to roughly eight percent of global warming. In addition, buildings are responsible for

Environmental Burdens Of Buildings, U.S. Data			
Resource Use	**% of Total**	**Pollution Emission**	**% of Total**
Raw Materials	30	Atmospheric Emissions	40
Energy Use	42	Water Effluents	20
Water Use	25	Solid Waste	25
Land (in SMSAs)	12	Other Releases	13

Figure 1.1—3 (Levin, 2003)

136 million tons of waste from construction and demolition annually (Building Green, 2003). The United States demolishes 44,000 commercial buildings annually (U.S. EPA, 1998). Over 30 percent of the United States's landfills consist of construction debris (Zeiher, 1996). The average American household produces 3,500 pounds of garbage, 450,000 gallons of wastewater and 25,000 pounds of carbon dioxide, along with small amounts of sulfur dioxide, nitrogen oxides, and heavy metals annually (Barnett, 1998). Building design professionals may play a large role in tackling the underlying causes of environmental, social, and economic degradation.

1.2 Environmentalism versus Sustainability

Sustainability is often confused with the environmental movement of the late 1960s and early 1970s. The two are not synonymous.

1.2.1 Environmentalism

The environmental architecture movement started in the late 1960s as a response to the energy crisis. It also was responding to Rachel Carson's book, *Silent Spring*, first published in 1962, which led to the founding of the Environmental Protection Agency, in 1970. Environmental architecture was a grassroots movement focused on conserving energy and protecting nature for nature's sake. Architects responded to this by focusing on energy conservation. They explored solar and photovoltaic technologies, optimum orientation, diurnal zoning, and self-sufficiency (Steele, 1997). One example of this was the push for solar homes. In the

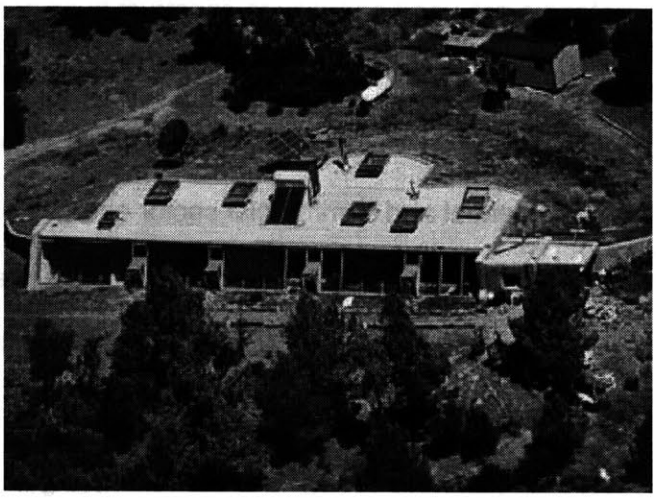


Figure 1.2—1 Earthship home near Durango, Colorado

Arizona deserts they buried buildings into the earth to minimize solar heat gain and used the earth's thermal mass to keep their buildings cool. These structures, known as earthships, were and are extremely effective in reducing the need for additional cooling. (See Figure 1.2-1.) Mainstream society considered these structures as radical. As the energy crisis diminished, solar panels, wind turbines, thermal mass strategies, rainwater harvesting, and composting toilets became less critical.

1.2.2 Sustainability

According to James Steele, associate professor of architecture at the University of Southern California, and author of *Sustainable Architecture*, "The subtle philosophical shift that has taken place since the first Earth Day in 1970 has been the concept of sustainability rather than ecology"(Steele, 1997). Sustainability encompasses all those sensibilities found in environmentalism, but significantly exceeds them in substance and scope. The 1987, the Brundtland Commission Report first defined sustainability as, "meeting the needs of the present without compromising the ability of future generations to meet their own needs." Sustainability strives towards improving the environment, the economy, and increasing social justice. A major distinction between environmentalism and sustainability is the shift from a grassroots movement to one that includes of major corporations, entire industries, and governments. Globally, large companies including Nike, Ford Motor Company, the Gap, Interface Inc., and British Petroleum (also known as Beyond Petroleum), are striving towards sustainable business models. There is an interesting and crucial relationship between these large corporations and government, nonprofits, and grassroots organizations. Clear examples of this shift is the husband and wife team, Pliny Fiske and Gail Vittori, both of the Center for Maximum Potential Building Systems (See Figure 1-4). Until recently, mainstream architects considered their research radical and rarely gave them much attention. Today, the couple is among the most sought after "green" consultants in the industry. Their clients include the UT/Houston Health Science Center, which

is spending millions of dollars in research for its new campus. The university is one of the greenest in Texas and aims for LEED Platinum ratings. Fiske and Vittori also are working on an initiative with the Department of Defense to "green" the Pentagon City of and a project for the city of Seattle called, "Seattle green Building Initiatives."

1.2.2.1 The Natural Step

As corporations, government organizations, and individuals realize it is impossible to ignore the global environmental crisis, they look for solutions. Many are turning to the Natural Step, (TNS) a nonprofit organization founded in Sweden in 1998 under the leadership of Dr. Karl-Henrik Robert. TNS helps organizations and governments integrate sustainability into core strategies and operations. According to Robert, TNS is a framework for overall planning to be used with other activities, concepts and tools (Robert, 2000). It stresses the values of principles over details and offers a shared framework with a common language. It also focuses on life-cycle analysis, in particular the earlier phases.

The underlying framework for TNS is four, non-negotiable, system conditions. First, substances from the Earth's crust must not systematically increase in nature. Fossil fuels, metals, and other minerals must not be extracted at a faster rate than their slow redeposit into the Earth's crust. For example, even if we recycle 95 percent of all batteries containing cadmium, and in each technical cycle only 5 percent escapes into nature, a time will come when the entire cadmium content from our mines has leaked into nature. In other words, there will be a systematic increase in nature. The rationale for recycling minerals from the Earth's crust is that it should lie so efficient that we do not need to take more from the Earth's crust than is slowly redeposited. Second, substances produced by society must not systematically increase in nature. They must not be produced faster than they can be broken down and be reintegrated into the cycles of nature or be deposited in the Earth's crust. At present there are around 70,000 substances – PCBs, DDT, dioxins, bromide organic compounds are just a few examples – which cannot be processed by nature. Even substances that nature can handle must not be

produced at a faster rate than they can be broken down and integrated into nature's cycles deposited into the Earth's crust. Third, The physical basis for the productivity and diversity of nature must not be systematically diminished. Productive surfaces of nature must not be diminished in quality. We must not harvest more from nature than can be recreated or renewed. We cannot keep putting ever-increasing amounts of asphalt over green surfaces, or allowing forests to turn into deserts, or agricultural soils to be degraded, or harvesting fish stocks faster than they can regenerate. Lastly, there must be fair and efficient use of resources with respect to meeting human needs. Basic human needs must be met with the most resource-efficient methods possible, including equitable resource distribution. The world's wealthiest 16 percent using 80 percent of natural resources is neither efficient or fair (Robert, 1995).

Sustainability in Business

According to Dr. Stuart Hart, a professor at the University of North Carolina's business school, "Over the next decade or so, sustainable development will constitute one of the biggest opportunities in the history of commerce". Paul Hawken and Hunter and Amory Lovins state in their book, *Natural Capitalism*, "There is now sufficient evidence to suggest that if your institution is not paying attention to this [sustainable business] revolution, it will lose competitive advantage." Major corporations recognize the importance of reducing the negative effects they have on the environment and adopt TNS conditions as a framework for sustainability. The Home Depot, Nike, McDonalds, Bank of America, Air BP, Sun Microsystems, DuPont, Starbucks, the City of Seattle are all committed to TNS (TNS, 2003). Interface Inc., the world's largest producer of commercial floor coverings, and a Fortune 1000 company, is another example. Founded in 1973, the company manufactures and sells 40 percent of the world's commercial carpet tiles. It employs 7,400 people worldwide with annual sales of more than $1 billion. In 1997, Interface Inc. was the first company in the United States to publicly commit to adopting TNS. Since then, all Interface employees go through TNS training seminars. Interface is addressing seven fronts: Elimination of waste, benign emissions, renewable energy, life-cycle

thinking, resources-efficient transportation, sensitive hookup, and redesign commerce. With the long-term goal of zero waste, in the first year it captured $20 million through source reduction and recycling. The company is investing in research on recycled fibers and is beginning to shift to the paradigm of service instead of product, with its Evergreen Lease program. As well, the company is committed to energy efficiency and solar power. According to Interface's latest sustainability report, the company has saved $185 million since 1995 by eliminating waste. Interface has reduced its nonrenewable process energy by more than 18 percent since 1996. The company's 2005 goal is to maintain renewable energy at 10 percent of its total energy. Since 1996, Interface has decreased its average water consumption per unit of product by 26 percent. In 2000, it increased its use of non-petro-based materials to 24 percent (Interface, 2001). In 2002, the United States Green Building Council recognized the company's achievements by honoring its CEO, Ray Anderson. Mr. Anderson states, "My mission is to transform my company to one based on cyclical systems that are waste free and resource efficient by committing to the principles of The Natural Step."

1.2.2.3 What Is Green Building?

Green architecture uses the principles of sustainability to minimize buildings' ecological footprints. Sustainable building goes beyond ecological issues and tries to make a connection to other buildings, local typologies, regional microclimates, and materials (Steele, 1997). The buildings are functional in that they meet the needs of the users. They minimize their ecological footprint and use carbon dioxide balancing as a measure. They minimize energy consumption and may even produce energy. They are durable and flexible. But, they must allow for program changes over time. A sustainable building's characteristics may include better insulation, efficient lights and mechanical systems. Some buildings may use alternative energy as well as water conservation features. They may incorporate recycled, rapidly renewable, or reusable materials.

The materials are typically be low emitting and the building has good ventilation for improved indoor air quality. Sustainable designers aim to reduce building construction waste and re-sourcing waste products. They plan less environmentally destructive site development with runoff control and preservation of watercourses, natural vegetation, and habitats. The building may have on-site wastewater treatment and will definitely have reduced or zero use of ozone-depleting substances. The design team will engage in life cycle assessment of materials and building systems and conduct a formal environmental impact assessment of total building. Lastly, there will be recycling provisions for occupants (Levin, 10).

1.3 Green Design Acceptance

Environmentally, socially, and economically responsive architecture is in fact gaining acceptance in the building industry. In the United States, this is evident in the exponential growth of United States Green Building Council members in the last five years. It is also evident in the number of firms boasting "green" capabilities. As part of this thesis, I interviewed a number of architecture and engineering firms formally and informally on the state of green building and found it is indeed gaining importance within their firms.

1.3.1 USGBC Growth

A clear sign of the acceptance of green architecture in the United States is the growth of the United States Green Building Council. The Council, roughly ten years old, boasts membership of more than 1000 organizations including product manufacturers such as United Technologies/Carrier, Herman Miller, and Armstrong World Industries; environmental leaders such as the Natural Resources Defense Council, the Rocky Mountain Institute, and the Audubon Society; building and design professionals including the American Society of Interior Designers and the American Institute of Architects; retailers and building owners such as The Gap and Target Stores; and financial industry leaders including the Bank of America. Of their members, approximately 400 are architects and membership is growing. The USGBC saw a

300 percent increase between 1999 and 2001. The strength and diversity of the USGBC coalition significantly enhances the resources available and the effectiveness of member efforts to improve the quality of our buildings. Its voice is credible and powerful because of the broad representation and balance of membership. No other organization represents the entire green building industry. One of the USGBC's major contributions is the development of, Leadership in Energy and Environmental Design (LEED), a green building rating program. The release of LEED and the increase in sustainable building dialogue is not coincidental. Almost 2,500 people have attended LEED workshops since its inception. There were more than 3,000 people at the USGBC's first annual International Green Building Conference in Austin, Texas, in November 2002. While there are only 27 LEED certified buildings built as of August 2002, the USGBC currently lists 515 projects registered in the LEED process. This includes 60 million gross square feet in 45 states and 6 countries (USGBC, 2003). The USGBC estimates that somewhere between three and six percent of all new commercial building square footage in the United States is being designed with the LEED checklist as a guide (Malin, 45) (See Figure 1.3-1).

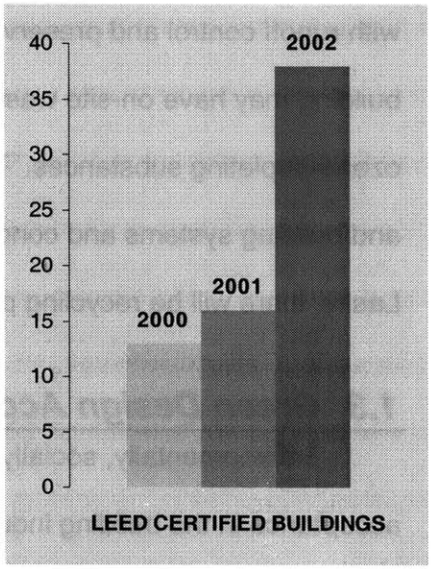


Figure 1.3—1 (Malin, 2003)

1.3.2 Firms with Green Services

It is hard to find, among the largest and most respected architecture firms, an office that does not claim to be doing something relative to green architecture. This is a different scene than 5 years ago, before the release of LEED. Hellmuth, Obata + Kassabaum Inc (HOK), ranked first of United States-based architecture/engineering firms for 2002 by *ENR & World Architecture*, employs 1,800 people in 24 offices worldwide. The American Institute of Architects Committee on the Environment has listed a total of 6 of HOK's buildings in the Top Ten Green

Projects since the committee started the program in 1998. HOK has earned LEED silver ratings for two of its buildings and has many buildings in the LEED registration process (HOK, 2003). Sandra Mendler, HOK San Francisco Vice President, is HOK's firm wide Sustainable Design Principal and its in-house expert. Mendler established an in-house research group that developed the "HOK Healthy and Sustainable Building Materials Database" and co-authored "The HOK Guidebook to Sustainable Design," published by John Wiley & Sons, Inc. She has also written numerous articles and appeared on local and national radio programs, including NPR (HOK, 2003).

Gensler, another large corporate firm, is also designing green. It has 1,800 employees, 500 of whom are registered architects. As of April 2003, Gensler has designed two LEED certified projects: the Detroit Lions Building in Detroit, Michigan and the Tivoli / IBM Building One in Austin, Texas. The company currently has two LEED registered projects, one LEED corporate interiors pilot project, and one LEED pioneer building, Armstrong World Industries, Lancaster, PA. Twenty-nine of Gensler's employees are LEED accredited professionals. While HOK and Gensler are leading corporate architecture firms in the green race, medium and small-sized architecture firms also are taking a stance relative to green design. For example, William Worn Architects in Chicago, an eight-person firm, is a USGBC member and has an accredited professional. Twenty-five architecture firms were represented at an architecture career fair at MIT in April 2003. Of those, twenty claimed they were doing green design and that they have been designing green for years.

In 2002, *Metropolis* commissioned a third-party research company to conduct a survey of visitors to MetropolisMag.com. Respondents were recruited at random via a pop-up window from the home page. A total of 560 surveys were gathered from design professionals, students, and educators. Ninety-three percent of the design professionals claimed they are interested in sustainable design and that 53 percent of their clients are interested. Sustainable design is sometimes or always desirable on 78 percent of their projects (Metropolis, 2002).

Another indicator of green building's growth and acceptance is the increasing number of LEED accredited professionals. LEED Accredited Professionals are design professionals who have demonstrated their knowledge of integrated design and their capacity to facilitate the LEED certification process on an exam given by the USGBC. The exam tests an individual's understanding of sustainable building principles, and familiarity with LEED requirements, resources, and processes (USGBC, 2003). The number of LEED accredited professionals has grown from none in the year 2000 to almost 2,500 in the year 2003 (Malin, 2003). (See Figure 1.3-2.)

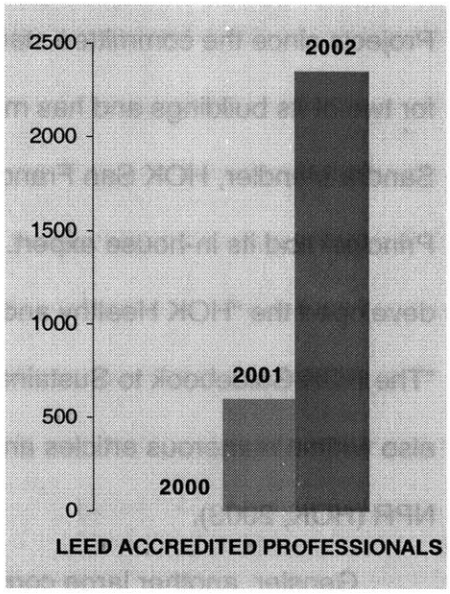


Figure 1.3—1 (Malin, 2003)

1.4 Obstacles to Green Buildings

Despite evidence that sustainable architecture is necessary and that design professionals are indeed embracing it, there are many obstacles to its continued growth, including perceived capital costs, current education methods and systems, uninformed and misdirected clients, the established design process, perceived risks, a lack of green building assessment methods, few incentives, little research, and shifted priorities. While some of these obstacles are indeed valid and will take policy shifts and investment to overcome, the majority of them are either based on incorrect mental models, hearsay and negative experiences, people's aversions to trying something new, or a lack of knowledge. These preconceptions often pose significant barriers to the adoption of innovative solutions.

1.4.1 Perceived Capital Costs

It is a common belief that environmentally, socially, and economically responsive buildings cost more than a traditional building. According to Nadav Malin, senior editor of *Environmental Building News*, "Going through the LEED process definitely adds to the soft costs

associated with a building. There are registration and application fees, the design-team labor required for the application, and the time needed to optimize the design for energy efficiency and other green metrics. In terms of overall construction costs, however, a LEED building need not cost more than a standard building (Malin, 2003.)"

The belief that construction costs increase with a sustainable building is based partly on design professionals' experiences with Band-Aid or bolt-on sustainable design solutions. Bill Reed, Vice President of Natural Logic, an environmental consulting firm, in Boston, Massachusetts, often shows a picture of a person dipping a toe into water as an analogy of the state of green design in the United States. People are not willing to dive right in and embrace it. They are too hesitant and instead take what some people call the Band-Aid approach to green design: trying to green the building after most of it is designed with little regard to environmental impact. Design professionals think of means of minimizing the environmental impact late in the process and inherently end up costing the client more money. An example of this is when a client does not think about building orientation as a design strategy and ends up with a building with significant east and west exposure, which, in turn, equates to large solar heat gains in the summer months and little heat gain in the winter. To Band-Aid this issue, the designers will either specify super-insulated windows or a complex sun/shade device on the facades, both of which are expensive solutions. Designers could negate these extra costs had they considered building orientation upfront.

A sustainable approach calls for an integrated design solution. It requires more time spent on the front-end of the design process with cost savings down the road. Designs, which are rigorous in seeking out inefficiencies and eliminating waste, provide economic benefits. Increased capital costs incurred in specific areas often can be offset elsewhere. For example, the Wessex Water Headquarters in Bath, Scotland, used prefabricated panels with increased capital costs of ten percent over concrete block. Savings, during on-site construction through

reduced time and defects outweighed the added capital costs by almost two times (Yates, 2001).

Another way to approach the issue of cost is a shift to life-cycle economics. Instead of thinking only of first costs, designers can help clients understand the long-term costs involved in operating and maintaining their building. Energy efficient buildings have attractive returns. For example, a three-year payback, typical in lighting retrofits, is equal to an internal rate of return in excess of 30 percent. The same retrofit may also cut energy use by 50 cents or more per square foot. In 1990, the International Facilities Management Association and the Electric Power Research Institute completed a study of 70 million square feet of office space. The survey found that electricity cost $1.53 per square foot and accounted for 85 percent of the total energy bill, while repairs and maintenance typically added another $1.37. According to Sandra Mendler, HOK's sustainable design principle, reductions in annual operating costs are typically multiplied by a factor of 10 in sustainable buildings.

Sustainable buildings are more valuable to owners and occupants. Savings in energy efficiency and maintenance are insignificant compared to the cost of employees. Typical American offices spend about 100 times as much per square foot for people in the forms of payroll, benefits, employer taxes, and individual equipment,

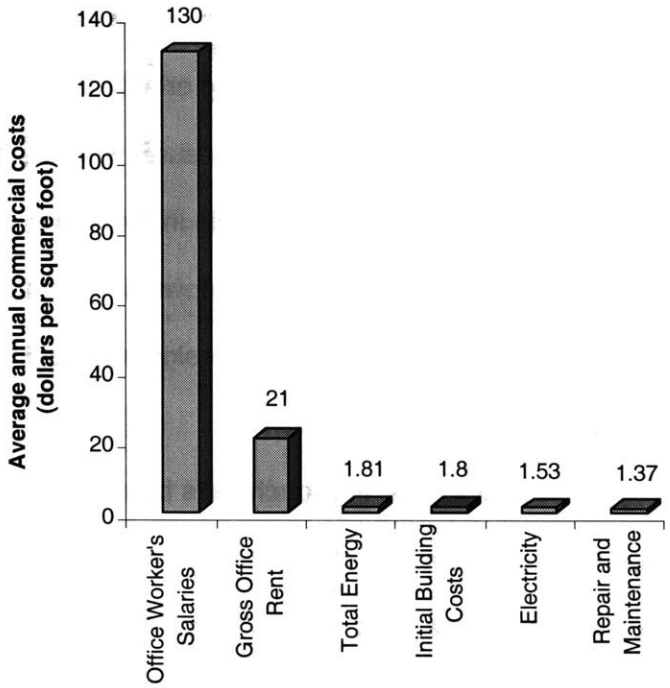


Figure 1.4—1 Source: Building Owners and Managers Association; Electric Power research Institute; Statistical Abstract of the United States 1991

as for energy. Considering Americans spend about 90 percent of their time in buildings it might not be surprising to learn the EPA estimates over $60 billion per year in medical health costs can be attributed to poor indoor air quality (Hawken, 1999). A small increase in productivity can provide savings to a company that exceeds its entire energy bill (Hawken, 1999). (See Figure 1.4.1.)

Mendler, of HOK, also claims, green buildings are easier to sell because they are in the public's favor. While many design professionals see cost as the primary impediment to green design, green buildings can be easier to finance, especially if the team explores utility incentive programs, manufacturers' discounts, government programs, and energy service contracts (Mendler, 2000).

Many factors contribute to added costs of all buildings, not just those that are certified green. Chris Schaffer, senior mechanical engineer at Ove Arup in Boston, Massachusetts, is working on a classroom building at Deerfield Academy, in Deerfield, Massachusetts. The design architect is Chicago based Skidmore, Owings & Merrill (SOM), one of the world's architecture, urban design, engineering, and interior architecture firms. The project budget is $380 per square foot, more than triple the budget for most public classroom buildings. The building is shooting for a LEED Gold rating. While the added costs may be in part due to green aspects, it completely ignores the fact that this building has a James Turrell installation in the lobby, a planetarium, interior brick and wood clad walls, and terrazzo floors. As Schaffer explains, star architects tend to have a greater understanding of building systems. This is how they are able to achieve innovative architecture. This innovation, however, costs money. Angled walls, atypical dimensions, and rare materials all increase the costs of building.

The graph below, compiled by Nigel Howard, USGBC vice president and LEED program director, illustrates that there is not a direct correlation between green building and increased costs. Green buildings do not get more expensive the greener they are. While some buildings are well above the average square foot cost of commercial construction in the United States,

others are well below. There are simply too many factors contributing to a building's overall cost to claim that all green buildings cost more. (See Figure 1.4-2.)

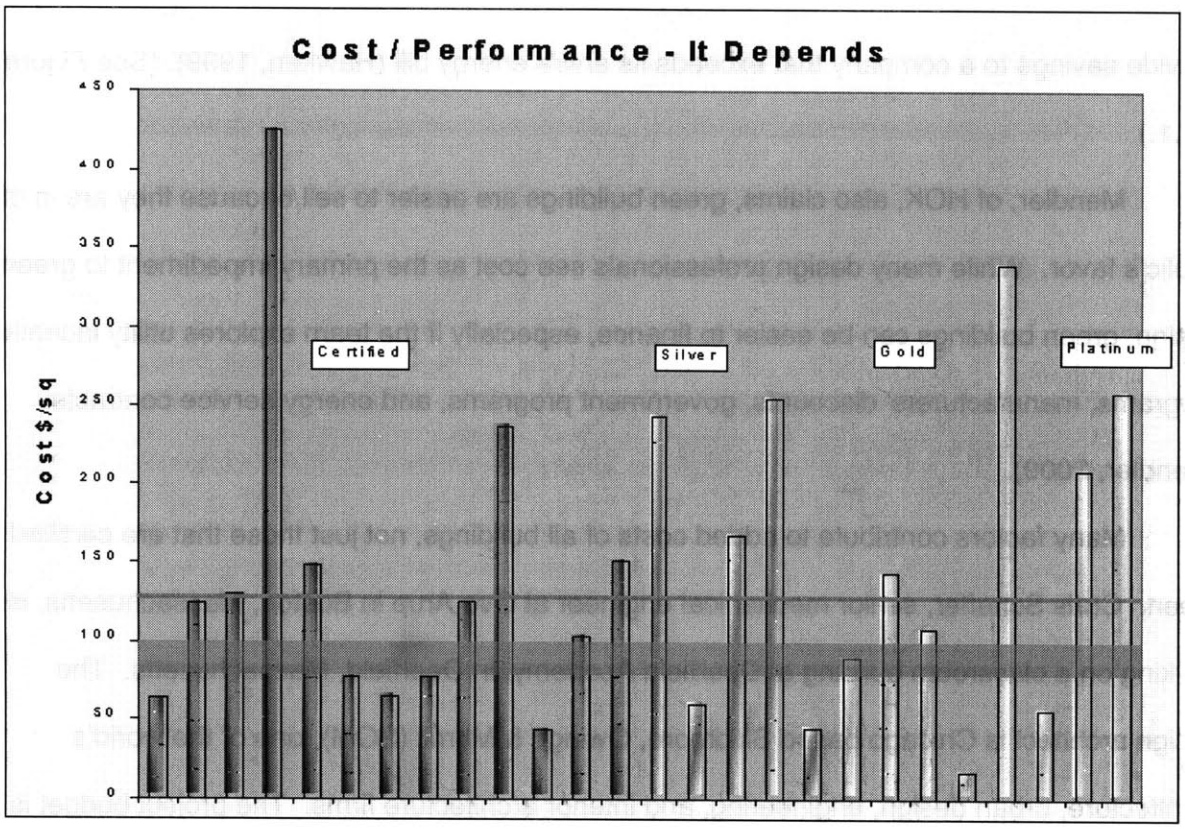


Figure 1.4—1 Nigel Howard (Director of LEED program and headquarters staff and operations, senior spokesperson for LEED) USGBC Expo (Austin, Nov. 2002)

1.4.2 Education

An additional obstacle to green building is current trends in design education. Architectural education, in the United States, in both academia and practice, are missing key elements of sustainable design. Most universities do not offer multiple courses on alternative design strategies. Design studios typically take precedent over all other courses. If sustainable strategies are not integrated into the design studios, students inevitably will fail to understand how to integrate these strategies into the buildings they design. Schools do no require students

to test if their buildings will work. Instead, they are asked to make beautiful objects. Scottish architect Rab Bennetts, designer of the Wessex Water Works, the building with the highest BREEAM rating to date, is particularly concerned about students and their recycling of heroic buildings. He sees students copying buildings with no idea whether their design will work. Students - and teachers - should have more facts about building performance to help them make better-informed decisions (Evans, 1998).

A clear impediment to including sustainable design strategies into the architectural design studio is the lack of educated professors. At the Massachusetts Institute of Technology, one of the top five architecture schools in the country, and arguably the best place to learn about technology, a premier design studio professor could not respond when asked about the environmental implications of using concrete with Portland cement. He had never heard concerns of cement's high embodied energy and responsibility for large amounts of carbon dioxide emissions into the atmosphere. According to Julia Mandell, assistant editor of *Architecture*, "The NAAB [National Architectural Accrediting Board] is currently debating whether sustainability will be a required criterion for school accreditation, or just an optional subject matter that can be accessed using the current set of standards. The American Institute of Architecture's Committee on the Environment would like to establish a national rating system for all architectural schools, so that there can be a public assessment of each school's commitment to sustainability in its curriculum (Mandell, 2003).

While most schools have yet to fully integrate sustainability within their curriculum, there are some exceptions. For instance, the University of Texas in Austin offers a degree in Energy and Environmental Design. The Massachusetts Institute of Technology gives students opportunities to engage in sustainable research projects with corporations like British Petroleum. They also are working to integrate the building systems curriculum into the design studio. Ball State University, in Muncie, Indiana, has established the Clustered Minors in Environmentally Sustainable Practices. The program allows students to substitute one of these

minors for the elective courses they would normally take. A graduate studio at Florida A&M recently designed a sustainable master plan for the University of St. Maarten. In addition, at Carnegie Mellon University, Vivian Loftness, head of the university's School of Architecture, is leading efforts to increase interaction between the building industry and academia through the Intelligent Workplace program. Here, professors and students perform research with sustainable materials and building systems built into the facility (Mandell, 2003).

While students may be able to learn more about sustainability in school, the majority of students obtain knowledge of construction details, project administration, construction management, client relations, and materials specification in the office. In fact, Architecture students must participate in the intern development program (IDP) before they can even apply to take the Architecture Registration Exams (ARE). Each intern chooses a mentor. Typically, firms do not give interns much responsibility, opportunity to express one's own ideas, or opportunities to be innovative. If the firms the interns work in are not practicing sustainable architecture, there is little chance the interns will develop proficient knowledge in sustainable strategies. The ARE does not require explicit knowledge of sustainable materials and systems.

In Metropolis's survey 86 percent of the students surveyed have interest in sustainable design. Sixty-two percent of them were not sure how many courses were offered on the subject in their schools and only two percent responded that there were five or more courses. Close to 70 percent said that sustainability was sometimes integrated into the curriculum and also only sometimes integrated into studio. Eighty-six percent of the educators who responded believed sustainability should be integrated into studios and 70 percent believed this would happen in the next five years or less. Of those surveyed, 27 percent claimed their own training is a barrier to implementing green design strategies in their school (Metropolis, 2003).

It takes specialist knowledge to incorporate environmental concerns into a design and often goes beyond the technical know-how of an architect who, when working within a group,

has to look for outside help. At first this might be with consultants but eventually the knowledge may permeate to the whole profession (Gangemi et al., 2000).

1.4.3 Clients

Architects typically only pursue sustainable design if the client requests it. Not all clients want the sort of service needed to achieve environmentally friendly architecture. Owner-occupiers are generally more receptive to discussions of life-cycle costs and are more conscious of the benefits to the building user. Clients building for immediate disposal believe low initial cost is the key issue and look only to comply with regulations. It is difficult to make green architecture faced with client indifference (Thermie, 1999). Nellie Reid, a LEED accredited professional and green building specialist at Gensler states, "A potential impediment is the degree to which we allow the client to steer the project away from responsible design for whatever reason. Financial constraints and code compliance (oddly enough) are also issues that sometimes restrict responsible design." This strategy is based on Gensler's mission to serve its clients.

1.4.4 Design Process

Many issues associated with current design processes stand in the way of green design. These problems start at the beginning of design when the client hires the architect. At this point, the site is typically already chosen, with disregard if it is appropriate for the building. The project team, including engineers and specialty consultants, often assembles well into the design process. Brian Malarkey, a designer at Kirksey, an architecture firm in Houston, says, "Currently we bring the MEP into the project too late to address many important sustainability issues." The architect is told the faster he builds, the better. The client gives little time or money for research. Professional performance of an architecture firm is conventionally judged according to its ability to deliver commissions that fulfill a clients expectations on-time, within a budget, carried out with the requisite technical skills and manpower and constructed to a high

standard (Dobney, 1998). According to architect Sim Van Der Ryn, city planners, engineers, and other design professionals have gotten trapped in standardized solutions that require enormous expenditures of energy and resources to implement. These standard templates, available as off-the–shelf recipes, are unconsciously adopted and replicated on a vast scale. The result fails to consider the health of human communities or of ecosystems, let alone the prerequisites of creating an actual place (Van Der Ryn, 1996).

Many clients now ask architects for a green building, but they do not always give the designer a formal brief with clear environmental objectives. It is then more important that the architects and thier consultants adopt a pro-active attitude in order to include alternative solutions in the design, which aim at the environmental quality of the building (Gangemi et al., 2000). The integration of environmental concerns into a project requires a whole new way of looking at design process management. Most significantly, within an architectural design group it becomes necessary to divide up environmental responsibilities, to base a client relationship on a genuine concern for the environment, and to find out about information sources and extra-disciplinary expertise (Gangemi et al., 2000).

1.4.5 Assessing Green Buildings

Current tools for assessing green buildings fail to measure a building's true environmental impact. This makes designing sustainably difficult. The absence of a valid assessment method is due, in part, to a lack of weighting within the current systems. As well, none of the current methods begin to address the social and economic aspects of sustainability and all of them require added time and money to process.

There is little connection, during the design process and after the building is built, how the building really is affecting the environment. Issues of site, energy, water, material, and indoor environmental quality (IEQ) as used by LEED are familiar issues to design professionals (Todd et al., 2001). In a system like LEED, it is easy to see if a strategy is used but hard to see

the effects of those strategies (Todd et al., 2001). All assessment systems are either organized around strategies or environmental performance. Users of systems that are structured around environmental concerns can see more readily the effects of their decisions. The problem with these is the necessity for design professionals' familiarity with these issues. A system that rates a building on all criteria presents a more complete assessment. When users can choose the criteria to be included in the scoring, negative aspects of the building are not reflected in the overall score. For instance, it is possible in LEED to achieve a rating level while completely ignoring issues of site or water. The potential disadvantage of the more complete approach is the cost and effort required for gathering data; if users can choose among criteria, they can decide whether gathering specific information required is worth the effort.

According to research architect Hal Levin, until recently, there has been no comprehensive effort to establish a systematic approach for evaluating total building environmental performance. Two exceptions are Building for Environmental and Economic Sustainability (BEES) and EcoQuantum. Both are comprehensive in scope, but both are years away from full development. There are numerous books and reports with discussions, advice, directions, and even scoring or rating systems for assessing the environmental performance of building features. The scoring is usually implicit or explicit in terms of a small number of discrete environmental goals. No apparent effort is made to assess the tradeoffs among various environmental objectives. Used most notably by BREEAM and LEED, this approach provides guidance to design professionals lacking any other basis for choosing less environmentally harmful building technologies. However, it is clearly an inadequate basis to determine whether a particular design element is sustainable. The GBC framework, an international assessment method, is beginning to include sustainability indicators such as total consumption of energy, land, water, as well as greenhouse gas emissions. Future versions of GBC will include more environmental performance indicators (Todd et al., 2001)

Typically, green design features address a single environmental problem and appear to be environmentally beneficial. There is no basis for comparison of the relative importance of energy consumption versus other environmental impacts such as water consumption, soil erosion, habitat destruction, or wastewater production; therefore, no basis for weighing the various impacts is available. It is necessary to weigh environmental impacts, normalize sources of similar impacts, and calculate the total environmental performance in order to determine which technology is appropriate. (Levin, 2003).

All assessment systems have inherent weighting. However, weighting is difficult since it cannot be accomplished with complete, or in some cases, any, scientific objectivity. Some organizations use consensus-based weighting. In this approach, group of experts rank various elements, such as environmental issues, in terms of their relative importance and assign points to these elements. The ranking or scoring is then used to establish weights (Todd et al., 2001).

In addition to lacking a comprehensive approach for evaluating environmental impact and missing a clear method of weighting alternatives, current assessment tools do not include social and economic indicators of sustainability. Current assessment systems address the product (material) and/or building level. There is little or no consideration of the supporting infrastructure, community, or building stock levels(Todd et al., 2001). Initial building assessment tools have focused on incremental environmental improvements designed to produce "green" or "greener" buildings. Now, there is discussion of the need to bring sustainability concerns into the tools, including social and economic issues as well as environmental concerns (Todd et al., 2001).

Another problem with current assessment methods is that they require outside assessors. Assessment fees may be established centrally or may be left to the discretion of the assessors. The LEED system depends on the design team to gather required information and to submit documentation to the rating organization (Todd et al., 2001). According to the

USGBC, LEED documentation costs can be as low as $10 thousand for an experienced team to as high as $60 dollars for a team with little experience.

1.4.6 Lack of Incentives

Clearly there are benefits to green buildings, but for many design professionals there are few incentives to design green. For example, engineers often are paid as a percentage of the whole building cost. This method provides minimal incentive to reduce building costs (Hawken, 1999). Other times they are paid based on the cost of the mechanical systems they put into a building. So, there is little incentive to downsize systems. Chris Schaeffner, of Ove Arup, claims engineers will specify more efficient insulation, but will not factor this into sizing the units. Cost estimators, then, will account for added costs of better insulation, but continue to use their old rule of thumbs for pricing mechanical units, even though the units could probably be much smaller than expected because of the smart design.

1.4.7 Lack of Research

According to the USGBC, making a convincing business case for high performance green buildings is further hindered by insufficient research (2003). Private and public investment in building-related research is behind that of other sectors. The design, construction, and operation of buildings accounts for 20 percent of all U.S. economic activity and more than 40 percent of energy used and pollution generated. However, less than one percent of the federal research budget is allocated to buildings. Europeans spend six times as much on research and development of building systems. In addition, the National Institutes of Health and the National Science Foundation have no programs dedicated to building research, despite evidence that indoor environments affect health and learning (USGBC, 2002).

1.4.8 Accountability

For a building to be constructed, the drawings need to be stamped by licensed architects and engineers and approved by the local governance. This stamp holds the design

professionals responsible should something go wrong with the building in the future. For instance architects and engineers are held accountable if there is a structural failure like the Hyatt Regency walkway collapse, in Kansas City, Missouri, in 1981. Design professionals are not held accountable, however, if the building is inefficient in energy and materials use. Barbra Batshalom, founder and Executive Director of The Green Roundtable,Inc. (GRT) an independent non-profit organization whose mission is to mainstream sustainable design through strategic outreach, education, policy advocacy and technical assistance, confirms that engineers are rarely asked to provide the client with figures on building performance.

1.5 The Effects

1.5.1 Buildings

Despite the overwhelming acceptance of green building, these obstacles impede the industry's success. While many architecture firms claim they are designing "green" buildings, the majority of buildings designed are not sustainable. Of the 170,000 commercial buildings built in the United States annually, the USGBC estimates that only 3 to 6 percent of them follow the LEED checklist (Malin2003)(See Figure 1.5-1). There are less than 50 buildings rated by LEED and only 500 by BREEAM. Another 500 projects are registered in the LEED process. While this growth is exponential, the overall number of projects remains a small percentage of those built annually. As illustrated earlier, Gensler's interest in green architecture is an indicator of sustainability's

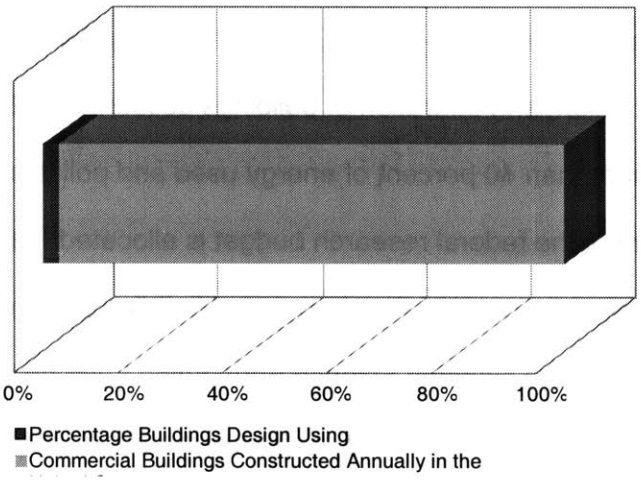


Figure 1.5—1

acceptance and growth of green building. However, Gensler's 6 LEED-rated buildings seem much less impressive when compared to the thousands of buildings the company has designed, and the hundreds it continues to design annually. Gensler's 29 LEED-accredited professionals also appear commendable, but they constitute less than 2 percent of its total employees. Banwell Architects, a 15-person firm in Lebanon, New Hampshire, is not a USGBC member but has designed the only LEED gold rated building to date in New England. The firm designs 4 to 6 buildings annually and has designed more than 300 projects total. That means 0.3 percent of its projects are green. Granted, Banwell may have designed green projects prior to LEED. Even so, LEED has been around for four years already. If it designs 4 to 6 buildings per year, shouldn't they all be LEED rated?

In addition to the small percentage of green buildings, the majority of those achieving rated levels are reaching only minimum requirements. To date, there are less than 2 LEED platinum buildings, 14 LEED gold buildings, 12 LEED silver buildings, and 26 LEED certified buildings (USGBC, 2003). Buildings reaching the minimum certified LEED levels advertise themselves as being environmentally friendly when indeed they still have significant ecological footprints. LEED, is a step but not the solution to reducing the impact buildings have on the environment.

1.6 Methods of Overcoming Obstacles

When asked, most design professionals think they know green principles. However, few truly understand green building systems and strategies. At an interview with Elton Hampton Architects, Nick Elton, a principle in the firm, admitted he did not understand when shown projects including thermal mass strategies. Chris Schaffner, Senior Mechanical Engineer at Over Arup Partners office in Boston, says when he mentions mechanical systems, most architects have little to no interest in how the systems work. Architects and engineers with little education and experience with green design are quick to state that the major obstacle to green

design is added costs. However those, with more sophisticated understanding of the issues, recognize education is a bigger issue. Steven Imrich, Senior Associate at Cambridge Seven Associates in Cambridge, Massachusetts, argues that cultural differences and lack of education of the client, architect, and consultants are the leading obstacles to green design.

1.6.1 Integrated Design Team

An integrated design team, improved education, and an easy way to access and discern between all the available resources and information are all means in overcoming these obstacles. The architectural design process is changing to accommodate sustainable buildings. To fully understand the scope of work, the context and a building's potential environmental impact, more time is devoted to research. The project team establishes sustainable goals and strategies at the initial meeting. It establishes clear definitions of responsibility. A key to this process is not seeing projects in isolation from one another. Each project builds upon past lessons and contributes to the future. Clients benefit from past research. Malaysian architect Ken Yeang sets a good example of the new architectural process. Yeang believes a high level of design integration, crossing traditional professional boundaries, and careful planning that takes the right steps in the right order, create synergies that both reduce cost and enhance performance. He maintains that in addition to the professional delivery process, architects must relate ecologically to our natural environment as a whole. Design work is a direct contribution towards a sustainable ecological future (Dobney, 1998). Yeang organizes his office around research and development carried out in rigors of practice. He conducts limited experiments with low risk and backed up fail-safe systems. Each project advances his bio-climatic hypothesis testing ideas and projecting new ideas forward into other projects. He guarantees his clients the latest developments, and

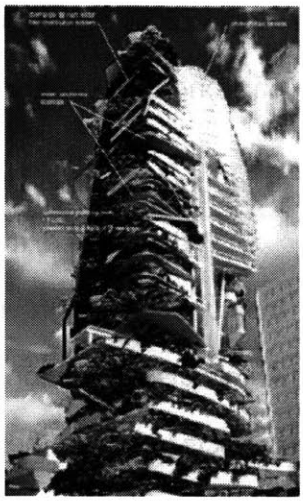


Figure 1.6—1 Ken Yeang, Tokyo-Nara Building (Yeang, 1999)

encourages them to accept responsibility for future developments (Dobney, 1998). Yeang demonstrates that architecture is necessarily a research-based activity. No two projects are ever the same, because conditions change from one site to another. (See Figure 1.6-1.)

For Rab Bennetts's Water Works, in Bath, Scotland, early in the design process the client established ambitious environmental criteria for the building. (See Figure 1.6-2.) It was required to be an excellent example of how a commercial building can be environmentally sustainable (Hawkes, 2000). All members of the design team, architects, structural and environmental engineers, cost consultants, landscape architects and construction managers, played a significant part in both setting targets for sustainability and ensuring they were achieved. The strategic brief demanded that the building meet strict environmental, social and economic requirements and also set demanding energy targets and required whole life performance and cost studies (Hawkes, 2000). Bennetts, a student of Arup's, pursues what Arup describes as "total design": the emphasis on structure, space and light resulting from mastery of technical requirements (Matheou, 1995). On projects deemed "green," Gensler and Associates also establishes goals and priorities early in the process. Gensler established a pre-design checklist to help ease the transition into green building. (See Figure 1.6-3).

Figure 1.6—2 Bennet's Wessex Water Works, Bath

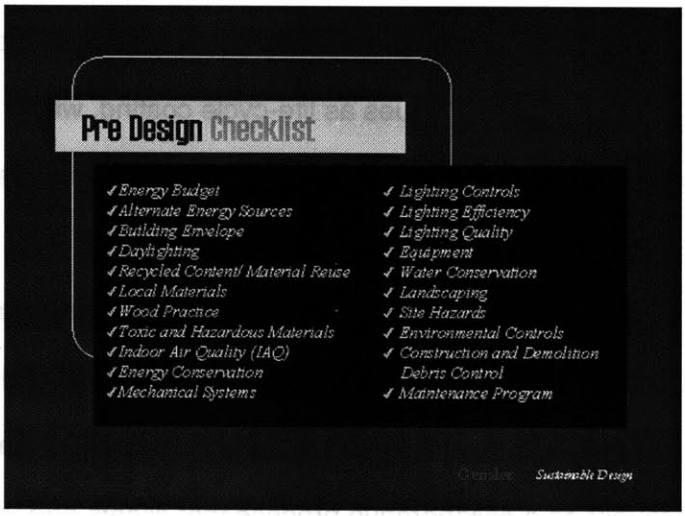


Figure 1.6—3 Gensler's Pre Design Checklist

With an integrated approach, the architecture and systems become one. Sustainable design strategies cannot be easily taken out of the project because they are integrated with the building. However, once you start along a path, it can be restraining. It requires confidence and trust between the architect and engineer.

1.6.2 Education

With the growing importance of renewable energy and energy efficient technologies, there is an urgent need to integrate the new knowledge in these fields into the curricula of universities and professional education (Hui and Cheung,1999). Education is a key factor for the promotion of building energy efficiency and solar energy applications since development of these technologies depends on the design professional's understanding and awareness, adequate information for design analysis, and sufficient manpower with technical and management skills (Hui and Cheung, 1999). According to, James Steele, associate professor of architecture at the University of Southern California, and author of *Sustainable Architecture*: "Reading as much literature in this area as possible and keeping track of progress being made toward a green index as part of the gross national product, particularly as it relates to resources, is one way to increase knowledge, which architects today can ill afford to do without. This should extend to such critical techniques as life-cycle costing, which is proving to be a much more accurate measure of the relative financial burden of resource processing into building materials (Steele, 1997)."

In order to advance the sustainable building industry, the profession must evaluate the architectural education process. The architect's education needs to be integrated with that of his fellow students. Architect Sim Van Der Ryn, claims, "Architectural design is generally not taught as a collaborative process that clients and users have any stake in. Rather it is often taught as a 'pure' process that should not be 'contaminated' by any real-world constraints or needs: social, environmental, or economic. It is even fashionable to approach design education

as a form of personal therapy - the artist's struggle for self-expression" (Van Der Ryn, 1996). More emphasis clearly needs to be placed on engineering and understanding natural systems. Technology of architecture professor, Virginia Gangemi, at the University of Naples Federico II, we need a training program capable of creating a professional who is equipped with all the necessary culture for an architect but ready for the specialist skills he needs to allow him to manage input from all sorts of different disciplinary fields (Gangemi et al., 2000). The architecture registration exam should test a fundamental knowledge and understanding of sustainable design. Young architects must understand the full implications of their building and comprehend strategies that can help minimize the building industry's footprint. This will produce minimal results if it is done in isolation of the profession as a whole. Gensler has a Sustainable Design Task Force that promotes green building. In Gensler's major offices, Sustainable Design Committees provide education at a local level. The task force has created a firm-wide Sustainable Design course. It also subscribes to many green building publications, provide updates via email, and has green materials libraries in several offices. In addition, Gensler encourages employees to attend green building events and become LEED accredited. Other firms, like Kirksey, in Houston, encourage all employees to attend The Natural Step Training Seminars and send green committee representatives to various green building conferences. Both Gensler and Kirksey are involved in starting USGBC chapters in their localities as outreach to the rest of the community.

1.7 Resources Available

Numerous resources are available for education and practice of environmentally, socially, and economically responsive architecture including books, journals, computer programs, web pages, videos, audiotapes, organizations, email groups and countless individuals. The problem is how to identify and sort these resources. The majority of designers interviewed for a survey carried out on behalf of the Building Research Establishment claim that the main sources of

information on environmental issues are represented by specialized journals and publications (Gangemi et al., 2000). For environmental or climatic analyses and calculations, the designers turn to specialty consultants. Particularly with the growth in popularity of low-energy design, the consultant's work has become much more complex and vital to the project's success (Gangemi et al., 2000). Many consultants still do not have the tools to design sustainably. In addition, using consultants can be costly. It is important then for architects to have access directly to resources to guide them in their use and interaction with consultants. (See the appendix for a complete list of resources included in BridgeGreen to date.)

1.7.1 Organizations

There are many organizations focused on "greening" the industry including the United States Green Building Council (USGBC), the Coalition for Environmentally Responsible Economies (CERES), The Smart Growth Network, the Urban Land Institute (ULI), The Natural Step, and The Green Building Challenge (GBC). The USGBC, founded in 1993, has been instrumental in unifying and propelling the green building industry in the United States. The Smart Growth Network and ULI focus their interests beyond the individual building and look at the greater implications of sustainable development. CERES and TNS are umbrella organizations, which help all industries establish goals and enhance the quality of the environment. These organizations serve to bring together industries, companies, and individuals with similar goals. They provide framework and support. Although they do not necessarily provide answers, they can be instrumental in design professionals and their clients' sustainable pursuits.

1.7.2 Consultants

Design professionals turn to green building consultants for specialty knowledge they lack. These include Hunter and Amory Lovins's Rocky Mountain Institute (RMI) in Snowmass, Colorado, Pliny and Gail Fiske's Center for Maximum Potential Building Systems (CMPBS) in

Austin, Texas, and Barbra Batshalom's Green Roundtable (GRT) in Cambridge, Massachusetts. In a survey by Expertise Marketing in 2000, 83 percent of architecture, engineering, and construction firms with environmental concerns hired specialized consultants in the past year (Lowe, 2000).

RMI is a nonprofit organization that fosters the efficient and restorative use of natural, human and other capital to make the world more secure, just, prosperous, and life sustaining. It does this by inspiring business, civil society, and government to design integrative solutions that create wealth. Its staff shows businesses, communities, individuals, and governments how to create more wealth and employment, protect and enhance natural and human capital, increase profit and competitive advantage, and enjoy many other benefits—largely by doing what they do far more efficiently (RMI, 2003). It is standard for Gensler, one of the largest architecture firms in the world, to call RMI early in the design process to consult on green building projects.

CMPBS uses life-cycle design to foster ecological balance within a multi-scalar context and engages in interdisciplinary collaborations with a common vision of healthful environments, economic prosperity, and social equity. It offers services for public and private clients for building and master planning design, lectures, policy initiatives, tools for green specification, and LEED project management (CMPBS, 2003). (See Figure 1.7-1.)

Figure 1.7—1 CMPBS Demonstration House, Austin, TX

GRT is an independent non-profit organization whose mission is to support sustainable development. It provides a forum for dialogue among various professionals. Its strategy is to educate building operators and to train and support design professionals. It also works with regulatory bodies to promote the requirement of sustainable design (GRT, 2003). GRT gets

calls from policy makers and designers for information on sustainability. It works with roughly 25 companies in varying capacities in the course of one year (Batshalom, 2003).

1.7.3 Tools

According to Wayne Trusty, President of the Athena Sustainable Materials Institute, there are numerous tools for sustainable design specific to the building industry. They can be divided into three categories: product comparison, building design or decision support, and whole building assessment frameworks (Trusty, 2000).

Product comparison tools can help designers choose more environmentally friendly products. One example is Building for Environmental and Economic Sustainability software (BEES). The program balances the environmental and economic performance of building products. BEES targets designers, builders, and product manufacturers. It includes actual economic and environmental performance data for more than 200 building products. It measures environmental performance of building products using environmental life cycle assessment methods specified in ISO 14040 standards. Other references like Oikos or GreenSpec also provide product information in terms of environmental performance. Oikos is an online reference while GreenSpec is in both manual and CD format. GreenSpec organizes environmentally preferable materials according to Construction Standards Institute (CSI) format. It describes the environmental issues associated with the material or product, gives manufacturer information, and provides sample specifications.

Building decision tools focus on different building systems. They may include energy analysis, computational fluid dynamics for air flow and ventilation studies, lighting analysis, acoustical models, moisture analysis, and life cycle assessment. Athena, a life-cycle assessment tool, DOE-2 and EnergyPlus energy simulation programs, and the Green Building Advisor (GBA) – an interactive computer application – are all examples of existing building design and decision support tools designers can use during the design process to produce

environmentally responsible buildings. Chris Schaffner, of Ove Arup, claims that the GBA was the best $200 investment he ever made. "....a client calls and asks for suggestions – all I have to do is go the Green Building Advisor and it gives a valuable bullet point list of strategies. Also it lets me know that other people have thought about the same thing as I have like using recycled content concrete."

Whole building assessment frameworks have not been around long and, as stated earlier, are still wrought with many problems. The international initiative called The Green Building Challenge (GBC) promotes a valuable whole building assessment program, the GBTool. The GBTool, introduced in 1995, was the earliest assessment system to emerge. It is different from other models because it emphasizes research and involves researchers and practitioners worldwide. The GBC intended to contribute to the state-of-the-art of building performance assessment and provide a forum for identification and discussion of issues and testing of potential approaches. Since the GBTool's introduction, many countries followed the its model and developed their own systems. The USGBC developed LEED. Developed by the USGBC membership, LEED is a national consensus-based, market-driven building rating system designed to accelerate the development and implementation of green building practices. The full program offers training workshops, professional accreditation, resource support and third-party certification of building performance. The current version of the rating system, LEED 2.0, was launched in March 2000 following review by the entire USGBC membership and a national pilot testing program. LEED 2.0 is designed for rating new and existing commercial, institutional and high-rise residential buildings; however, active member committees are developing criteria addressing new project types. Buildings are given points for achieving certain criteria related to the site, energy, water, materials, and indoor environment and receive a rating of platinum, gold, silver or certified. The United Kingdom features BREEAM, a rating system that accesses buildings' environmental impacts and assigns either positive or negative values.

1.7.4 Books

Countless books dating back to the late 1960s and 1970s are resources for sustainable design. The pivotal book of the environmental movement was Rachel Carson's, *Silent Spring,* published in 1962. In it, Carson exposed the widespread use of pesticides and the countless hazards associated with them. Aldo Leopold's *A Sand County Almanac,* is a series of essays on themes of human relationship with wildlife and the land. Leopold was a biologist and professor. He played a significant role in the development of conservation organizations like the National Wildlife Federation and the Wilderness Society. Victor Olgay's, *Design with Climate* illustrate clearly, for the first time in 1962, how to design a building with climate in consideration. In 1969 *Design With Nature* landscape architect Ian McHarg illustrates how mapping sites natural and manmade systems can determine schemes for development. It promoted the idea of understanding the earth as a series of ecological layers that relate to and inform each other. This was groundbreaking, and was the predecessor to current techniques such as geographic information systems, environmental impact statements, and conservation planning and design Sustainability was not defined until 1987 when The World Commission on Environment and Development published *Our Common Future.* Each year since, more and more books are published regarding sustainability. The Rocky Mountain Institute's 1995 *Primer on Sustainable Building* was the first to introduce sustainable issues pertaining to building. Written for architects, developers, contractors, builders, planners and homeowners, the book presents a new way of thinking about architecture. It demonstrates how sustainable building design can enhance marketability and affordability while dramatically reducing resource consumption, environmental impacts and operating costs. *The HOK Guidebook to Sustainable Design,* written by HOK's Sandra Mendler in 2000, provides strategies for design professionals at different design stages. In this comprehensive guide, the world's largest architectural/engineering design firm helps architects, engineers, planners, interior designers, and landscape architects integrate sustainable design strategies into their work. Featuring

twenty-four case studies of a variety of international HOK projects, it shows how sustainable design thinking can improve projects within the conventional constraints of budget, schedule, and market demand. It also provides practical guidelines that enhance real projects, including urban planning, site design, buildings, interiors, and renovations. William McDonough's *Cradle to Cradle 2002* challenges the basic principles behind design. Paul Hawken with Hunter and Amory Lovins challenge us to consider the value of nature in our making of products in *Natural Capitalism,* published in 1999, and Janine Beynus's1997 *Biomimcry* directs us to nature for clues on how to live sustainably.

1.7.5 Journals

Among the best resources for sustainable building are *Environmental Building News (EBN), Building Research and Information, Environmental Design and Construction.* *Environmental Building News* (*EBN*) is a monthly newsletter featuring information on a wide range of topics related to sustainable building--from energy efficiency and recycled-content materials to land-use planning and indoor air quality. *EBN* is independently published, carries no advertising, and is not sponsored by any industry or related corporation. This ensures editorial freedom and avoids any hint of bias. *EBN*'s objectivity has earned the newsletter the distinction of being widely respected by both environmental activists and industry groups. According to Oberlin College Professor David Orr, "Environmental Building News has established the benchmark for relevance, insight, and usefulness in the green building field. It is the single most important and reliable publication in a fast-moving field. It is essential reading for architects, builders, consultants, and everyone interested in high performance buildings."

Building Research & Information is a bimonthly, international, journal serving professionals in the design, construction and property sectors. The Journal brings together ideas, developments, demonstration projects, case studies, innovative practices, feedback and

stimulates discussion and debates across the spectrum of design, material, construction, organizational, environmental, market, user and research management topics.

Environmental Design and Construction is a bi-monthly magazine that reports on the innovative products, strategies and technologies that are driving the industry's success. Covering such topics as resource and energy efficiency, alternative and renewable energy sources, indoor air quality, and life cycle assessment, *EDC* motivates and educates commercial and residential building teams, including architects, interior designers, facility managers, engineers, contractors, and building owners.

1.7.6 Web pages

Countless valuable web pages exist regarding sustainable design. BuildingGreen.com is by far one of the most useful and most frequently visited sites. It hosts *EBN* and provides access to all of its articles. As well, one can purchase GreenSpec, Green Building Advisor, and the *EBN* archives. It also provides access to join internet cafes on sustainability. It is often a first resource for researching specific green building topics. The U.S. DOE's website is also valuable. It hosts the largest compilation of green building case studies as well as numerous tools for energy modeling. Oikos, EPA, RMI are just a few others with value of the thousands that exist.

1.7.7 Email Groups

A great resource for learning about green design is other people. An interesting way to converse with them is through established email groups. BigGreen, administered by Oikos and BuildingGreen, is a group focused on commercial and institutional buildings. This discussion group exists to promote communication between building professionals interested in environmentally responsible design and construction. Members include experts and novices. It is great way to connect people all over the world with different level of expertise. Members receive between 5 to 20 emails per day. Topics at the time of this thesis include questions

about commissioning specifications, carpet off-gasing, and a discussion of geo-thermal ground source heat pumps.

1.7.8 Universities

Another resource is colleges and universities. Within their halls professors and students stretch the limits of sustainability. Among those leading these research efforts in the United States are Carnegie Mellon University, University of Texas, Austin, University of Oregon, and the Massachusetts Institute of Technology.

1.7.9 Conferences

Conferences are important resources for sharing information. There are many conferences focused on sustainable building. *EBN* lists 22 between April and October 2003 on the back cover of its April 2003 issue. The two major conferences in the United States are the USGBC's greenbuild international conference and expo and *Green@work* and *Interior Source* magazines' EnvironDesign. Both conferences occur annually and draw a few thousand building industry members.

(See the Appendix for a list of resources and how to find them.)

1.8 Disconnect

Industry professionals, in particular architects, have the ability to reduce the ecological footprint associated with building. Tools do exist to assist designers in lessening the environmental impact of buildings. However, professionals, for the most part, do not know what these tools are, where to find them, who should use them, and when to use them in the design process. There is an enormous amount of information and it is often difficult to search for required information. Using an Internet search engine (such as Google) returns 1,450,000 results for sustainable design, 1,210,00 for green architecture, and 524,000 for energy modeling. The United States Department of Energy's (U.S. DOE), alone, lists over 250 energy-modeling tools. Much of the information found in these searches is not valuable. Sometimes

locating good information on the Internet is more a case of good fortune than good planning. Sam Hui and K.P. Cheung professors of architecture at the University of Hong Kong claim, " Existing and emerging technologies for energy efficiency are not widely understood and integrated into buildings. The dissemination and application of energy efficient technologies are often hindered by the lack of available and accessible information" (2000). To help solve this problem, the pair has developed a Web-based information system at the University of Hong Kong.

Harvard Planning and Real Estate's (HPRE) Sustainable Buildings Program Coordinator Elizabeth Cordero agrees there is a lot of good information for sustainable design and that it is difficult to sort through the information. She thinks it would be helpful to have all the information in one place (Cordero, 2003).

Metropolis Magazine's survey found 62 percent of the 560 respondents are self-taught with no formal education in sustainable building. Thirty-nine percent learned on the job while 18 percent rely on continuing education. Of those, 66 percent rely on general media, 35 percent on websites, and 32 percent on trade magazines. Asked if they felt equipped to take a job where green design is called for, seventy percent responded no but plan to be equipped in the future.

Steven Imrich, of Cambridge Seven and Associates, considers himself highly educated about issues of green design and claims he has been thinking and practicing them since the environmental energy-conscious architecture of the late 1960s. Imrich is one of the stated "green" experts at his firm and is preparing to take the LEED accreditation exam. However, he was not aware of the Green Building Advisor, a tool Ove Arup's Chris Schaffner, deemed invaluable in green design.Clearly, there is a need for a bridge between available resources and the design professionals they.

Barbra Batshalom, of the GRT, is working on a project called Regenerative Environments, which looks at the impacts of the built environment on watersheds. The Environmental Protection Agency, the Executive Office of Environmental Affairs, the Charles River Watershed

Association, the Massachusetts Water Resources Authority, along with the Boston Society of Architect's Committee on the Environment, Bill Reed, of Natural Logic, Beals and Thomas Engineering, and Horsely & Witten environmental consultants, with the GRT are developing a toolkit and outreach program to change best practices to be more aware of watershed. According to GRT's Batshalom, the Executive Office of Environmental Affairs, Massachusetts's State Agency that approves environmental impact reports, does not know how to support higher-level development. It does not understand the available tools and resources and more importantly cannot tell owners and design professionals about these resources. Trish Garrigan. Head of Water Policy, in a meeting with Batshalom and other organizations, did not understand the green building process and did not know what tools exist to assist designers. Batshalom says this is not only Garrigan's problem. Of the GRT's 3,000 members, Batshalom claims none of them know what all the tools are or how to use them effectively. She says there are so many evidences in her daily interactions that point to a disconnect between resources and design professionals. GRT's mission statement states, "The GRT strives to mainstream 'green' and ultimately become obsolete." Batshalom said, at the time this thesis was written, they are not there yet. Part of achieving GRT's mission to be obsolete is getting tools to people (Batshalom, 2003).

Adrien Pitts, a professor at the School of Architectural Studies at the University of Sheffield in the United Kingdom, like many other university professors, is exploring how to teach sustainable design. He claims that useful material exists, but for many access to such material is restricted. This is due to a lack of awareness, the costs of some material, uninformed teachers, and the breadth of information from other countries. He suggests a remedy be a database of source material, which could be freely and readily accessed. "The data included would be frequently updated and contain a useful description of the product; its availability; source language and suitability for courses given in other languages; contact address for rapid

provision of further information; and of course, cost. The number of users of the data provided could be substantial" (Pitts, 1996).

When asked if a tool that can identify critical decisions along the design process relative to building systems would be useful in setting sustainable goals, Omayya Kanafani, a LEED accredited professional at Guggenheimer Architects in New York City said, "Yes. The timeline for integrating green design in to the building process is critical. The sooner the integration the better and more comprehensive it can be. A tool that would identify all the steps and where they fit in the project schedule would be invaluable. It could potentially eliminate the need to hire consultants for that information." She also thought that a tool that gives resources to help make those decisions would be useful because print resources for green design are expensive and require constant upgrading. There are also so many areas to cover and information that could be useful. A centralize database with potential resources would be very helpful (Kanafani, 2003).

2.0 Thesis

This thesis proposes a means to bridge the disconnect between design professionals and available resources. Manifested in the form of an interactive web-based tool called BridgeGreen, it aims to disseminate resources to appropriate professionals, so they may make to informed decisions during the design process relative to environmental impact. It connects the desired resource to the professional at the appropriate phase in the design process. Resources typically focus on different building systems. The use of these resources can result in different environmental impacts. By establishing which building system design professionals are investigating and which environment impact they are concerned with at a particular design phase, it is possible to suggest a number of strategies and to help locate resources to implement those strategies. Increasing the number of informed decisions will inevitably decrease the negative impact buildings have on the environment.

2.1 BridgeGreen

2.1.1 Target User

One aspect of the sustainable design process is an integrated design team. In this case, the design team assembles early and all members contribute in decision making. While design professionals communicate with each other, a need remains for one person to act as coordinator or facilitator. This person does not necessarily have to be the architect, but in many instances is. BridgeGreen targets this project coordinator. As in any business, building design professionals equate time with money. The less time a professional spends using BridgeGreen, the better. As the primary user, the project coordinator forwards strategies and resources found in BridgeGreen to appropriate design team members at the beginning of each design phase. While there is nothing keeping other professionals from using BridgeGreen, it targets the coordinator to increase efficiency. (See Figure 2.1-1).

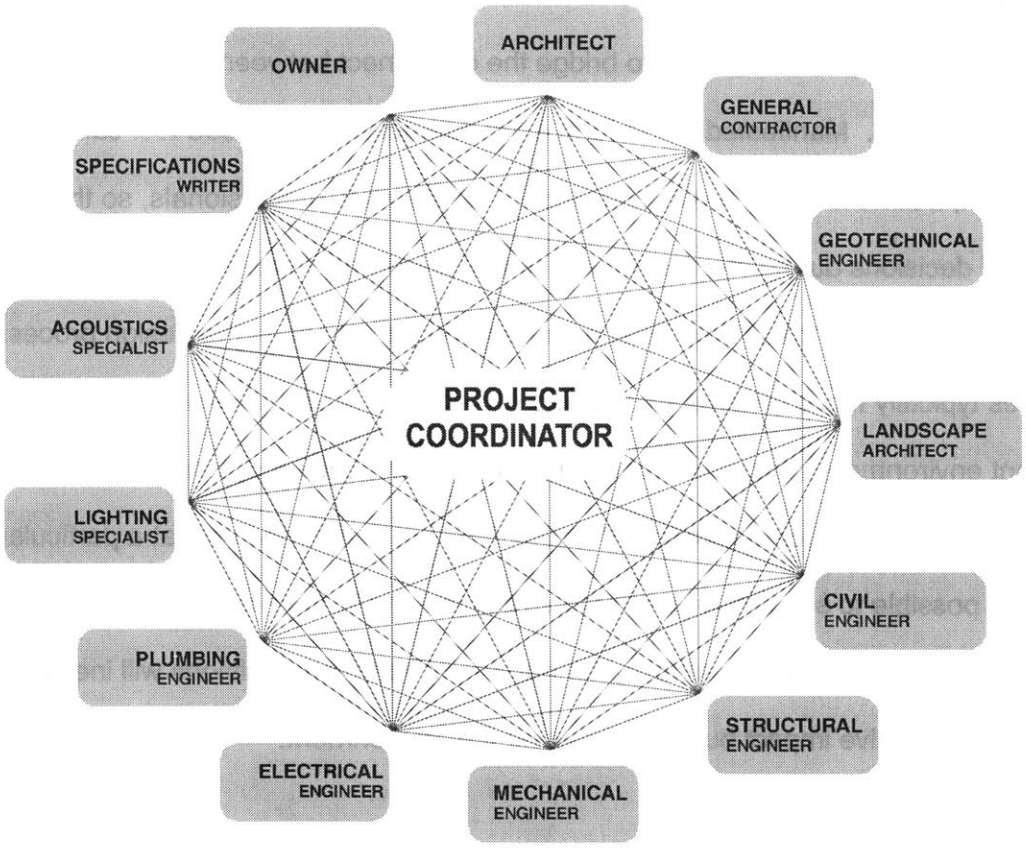


Figure 2.1—1 Design Team Organization

2.1.2 The Matrix

BridgeGreen connects desired resources to design professionals at appropriate phases in the design process. It does this by asking the user to select criteria in a matrix of project phases, design professionals, building systems, and environmental impacts. Buildings are composed of systems. Each system has a quantifiable environmental impact that contributes to the building's net impact. Design professionals are responsible for designing each building system and therefore, are responsible for the environmental impact of that system. In the United States, buildings design professionals work in a refined process divided into distinct phases. During each design phase, the professionals choose strategies that affect the building's environmental impact. (See Figure 2.1-2).

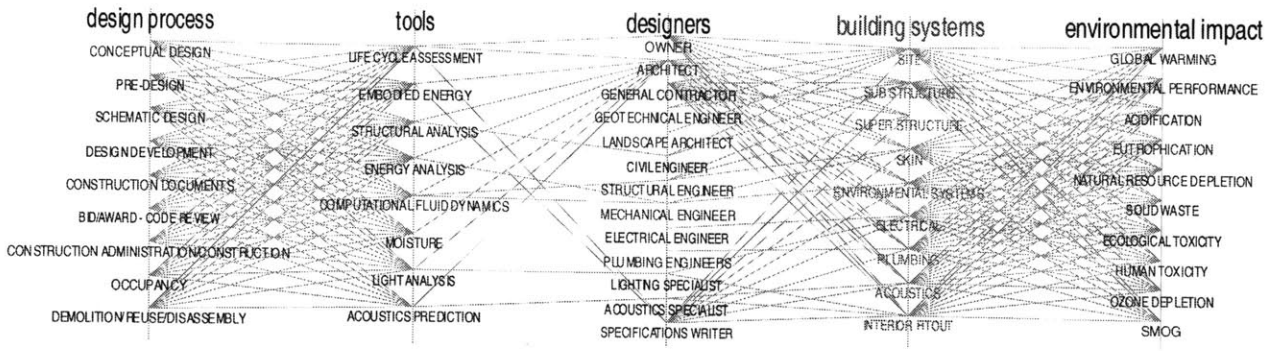


Figure 2.1—1 The Matrix

2.1.2.1 Building Systems

Frank Duffy, of DEGW and visiting critic at MIT, identifies four layers of a building: shell, services, scenery, and set. Stuart Brand, author of the *Whole Earth Catalog*, and co-founder of Global Business Network, elaborates further on these systems in his book, *How Buildings Learn* published in 1994. Brand separates buildings into site, structure, skin, services, space plan, and stuff. (See Figure 2.1-3.) For the purpose of this thesis, BridgeGreen expands further on these systems: site, sub-structure, super-structure, skin, environmental system, electrical, plumbing, interior fitout, lighting, and acoustics. (See Figure 2.1-4.) Duffy and Brand claim that each of these layers has a different rate of change (Brand, 1994). It is possible to analyze the life cycle of each of these systems and calculate its environmental impact. Buildings are designed and constructed relative to these systems. Many strategies can reduce the impacts. BridgeGreen links strategies with building systems. Each strategy may be associated with more than one building system. Design professionals, most often, design these systems separately and then fit them together to form a building. How the systems come together can be difficult and messy, especially if there is little coordination

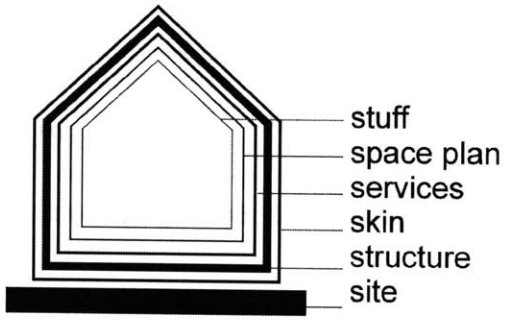


Figure 2.1—2 (Brand, 1994)

between the professionals, which is often the case. Sustainable design integrates building systems so that they work together. Overlapping systems is an efficient method to reduce environmental impacts. For instance, if the superstructure is concrete it may double as thermal mass as part of the environmental system.

Building System	
Site	The Site is the area of land a building sits on and the land surrounding it. The Site may extend beyond the property lines since the building may have an affect on the land and the land on it. It is critical to analise the site before beginning design.
Sub-Structure	The sub-structure refers to a buildings foundation. It is all of the structure sub-grade that the rest of the building is built upon.
Super-Structure	The super-structure is the building's main structural system. Choices in structural systems affects the flexibility, adaptability, and durability of a project. Material choices in the structural system may have large embodied energy.
Skin	The skin is of refered to as the building's exterior envelope. The skin is the buildings defense against the exterior environment.
Environmental Systems	Environmental Systems include systems for maintaining thermal comfort and Indoor air quality. These systems are often refered to as mechanical systems. Because it is not always necessary to use mechanical means to provide these comforts, we refer to the
Electrical	The electrical system includes all the electrical networking through wires and the systems attached to it. More and more interest is growing in providing on-site electrical sources.
Plumbing	Plumbing includes all systems including water. This includes toilets, sinks, showers, washing machines, irrigation, water catchment, waste water disposal, water recycling and purification.
Acoustics	An easy system to forget within a building, the Acoustical system ensures the aural comfort for a building occupant.
Interior Fitout	Interior fitout includes all the stuff that goes into a building. This includes, finishes, interior partitions, and furnishing. Over the lifetime of a building the Interior fitout typically has the highest ecological footprint.
Lighting	The lighting system accounts for both passive and active means for lighting a space. Often an afterthought in builidngs, recent studies prove the siginifance of natural light.

Figure 2.1—3 Building Systems

2.1.2.2 Environmental Impacts

As illustrated earlier in this document, buildings impact the environment significantly. However, during the design process, professionals rarely consider the environmental impact of their decisions. For example, designers may choose to reduce a building's energy consumption, but there is little direct correlation as to how that decision truly relates to global warming. As stated previously, one of the major obstacles to green building is that there is no good way to measure impacts. BridgeGreen aids designers in thinking about this issue by associating strategies and, subsequently, resources with environmental impacts. It does not

attempt to quantify impacts, but it does establish a hierarchy that indicates which impact is more important to consider relative to the other selected criteria. (See Figure.

Environmental Impacts	
Global Warming	The Earth's surface temperature has risen by one degree Fahrenheit in the past century, with accelerated warming during th past two decades. There is strong evidence that this warming is due to human activity. The gases resulting from human activity trap heat in the atmosphere.
Acidification	Sulfur dioxide(SO2) and nitrogen oxides(Nox) are the primary causes of acid rain. About 2/3 of all SO2 and 1/4 of all Nox, in the U.S., comes from electric power generation that relies on burning fossil fuels like coal. Acid deposition damages forests and soils, fish and other living things, materials, and human health. Acid rain also affects how clearly we see through air.
Eutrophication	Eutrophication is a condition in an aquatic ecosystem where high nutrient concentrations stimulate blooms of algae. Agricultural runoof, urban runoff, leaking spetic systems, sewer dischargews, eroded streambanks, and similar sources increase the flow of nutrients and organic substances into aquatic systems. Algal blooms cloud water and block sunlight causing grasses to die and destroying underwater habitat. In addition, algae choke bodies of water of mch needed Oxygen.
Non-renewable Resource Depletion	Currently we are depleting many resources at a faster rate than they can be recreated. Fossil Fules, and metals are good examples of these. Much debate exists on the extent of resources, but nontheless they are not infinite.
Habitat Alteration	Human activity can lead to damge of threatened and endangered speicies. Often this damgae is directly coorilated to land use.
Natural Resource Depletion	Humans are also depleting renewabel resources faster than they can recreated. Clear cutting forests is an example of this phenomenon.
Solid Waste	In 1999, U.S. residents, businesses, and instituitions produced more than 230 million tons of solid waste. That is about 4.6 pounds per person per day, up form 2.7 pounds per person per day in 1960. Major combatents to waste are source reduction, recycling, and composting.
Ecological Toxicity	The ecological toxicity impact measures the potential of a chemical released into the environment to harm terestrial nad aquatic ecosystems.
Human Toxicity	There are many potential human health effects form exposure to industrial and natural substances, ranging from transient irritation to permanent disability and even death.
Ozone Depletion	Destruction of the stratospheric ozone layer which shields the earth rom ultraviolet radiation harmul to life. This destruction of ozone is caused by the breakdown of certain chlorine and/or bromine containing compounds (chloroflourocarbons or halons), which break down when they reach the strotosphere and then catalytlically destroy ozone molocules.
Water Intake	This impact accesses the amount of water use. While water is abundant in many places it is believed I will be the highest environmental concern in the future.
Smog	Air pollution typically associated with oxidents. It leads to harmful impacts on human health and vegetation.
Indoor Air Quality	Indoor Air Quality has great effects on human health and productivity. IAQ is most often measured in volatile organic compound emissions (VOC). Formaldahydes in in composite woods, and fibers, hazardous chemicals, and particles released from some insulation products can also cause indoor air quality problems.

Figure 2.1—4 Environmental Impacts

2.1.2.3 Design Professionals

Traditional building design teams typically begin with an owner (the client) and architect. An owner hires an architect before or after selecting the site. The owner selects the architect through a design competition or by posting a request for proposals (RFP) or a request for qualifications (RFQ) and develops a "shortlist" from the submissions before conducting an interview. Clients may also outwardly hire architects they have previous experience with or on a referral from a colleague. Laws mandate procurement practices for government agencies. Depending on the size of the architectural practice there may be anywhere from one person to a team in the architecture firm working on the project over the course of its design. Different team members are involved in different stages of design with typically a small number of people actually following the job on a daily basis from start to completion. This is an important distinction for integrating green design into building practice. Each team member must be given or have the knowledge and tools for green design. According to green building specialist James Steele, architects are traditionally generalists, able to assimilate information and convert it into a design solution. Sustainability challenges that ability. He states, "To remain informed, architects must now digest an exponentially increasing amount of factual data with a wider variety of sources, requiring them to make the effort to search them out and to spend the extra time digesting them. Sustainability calls upon skills the architect uses best, analysis, cross-comparison, synthesis, and deduction, leading to aesthetic choices that have a basis in fact rather than fashion" (Steele, 1997).

The architect's job is to string together all the ideas suggested by the consultants, interpret them and integrate them into the overall architectural design (Gangemi et al., 2000). The architect's role is essential for the purposes of interdisciplinary and design coordination (Gangemi et al., 2000). Architects hires consultants at their discretion. The project scope determines the number of consultants. At minimum, for a commercial building, these will

include mechanical, electrical, and plumbing engineers, a civil engineer, and a structural engineer. They may also hire a landscape architect, lighting, acoustic, food service consultants, a specifications writer, an interior designer, a code expert, and other experts as needed. Traditionally, after the team designs the project, the client puts it to bid and hires a contractor. In some instances, the client engages with the contractor at the beginning stages of design. In this case, the contractor has a greater influence on the design. In most cases, the ultimate building occupants are excluded from the design process either because their opinion is not deemed valuable or because the building is being built without knowing the future tenants.

Typically, a project's design team is not integrated. The architect designs a building and passes it to the respective consultants to fit their appropriate technologies. After the architect has invested many hours in the project, there is little room for change if the consultant sees alternative solutions.

Contrarily, professionals for a sustainable building assemble early in the design process. They include the eventual building occupants in decision making and seek additional experts to aid in the design process. Biologists, chemists, geologists, water purification experts, and energy consultants may all play a role in future buildings. The team concept is crucial to the success of sustainable building. For architect Bob Berkibile, a principle of the Kansas City architecture firm, Berkibile Nelson Immenschuh McDowell Architects (BNIM) known for sustainable practices and "green" architecture, the most significant factor in his projects has been adding more diversity to the design and engineering team, including them at the outset and taking enough time to know the place, its ecology, culture, and economy before exploring design concepts (Zeiher, 1996). According to Berkibile, "Designers often seem to be paralyzed by what they perceive their knowledge or ignorance to be. Ecologically conscious design is less about what the individual knows or thinks, and more about approaching the design with a totally new consciousness and willingness to rely on the collaborative energy of all of the participants" (Zeiher, 1996). At the time of this thesis BNIM, was working on a new school of nursing and

public health at the University of Texas in Houston Health Science Center. Its project team includes experts in materials and carbon dioxide balancing, materials and systems engineering, day lighting, envelope studies, wastewater recycling, healthy building strategies, and energy strategies (UTH, 2003). (See Figure 2.1-6.)

Design Professionals	
Owner	The owner can be most important player on the design team. It is beneficial to include the owner in all phases of the design process.
Architect	The architect is often the first team member hired. The architect often serves as project coordinator. The architect is typically responsible for designing the building, coordinating building systems and overseeing construction.
General Contractor	The General Contractor is responsible for building the project. He/ she has a number of subcontractors working for him/ her. It is crucial for the contractor to be on board. Many of the problems associated with Green Building can be avoided if the GC is
Landscape Architect	The Landscape Architect works with the architect to design the property surrounding the building. The Landscape architect should have a comprehensive understanding of native species and be familiar with methods for reducing irrigation, fertilzers, and pe
Civil Engineer	The Civil Engineer coordinates utilities on site and drainage.
Mechanical Engineer	The Mechanical Engineer is the key person responsible for prividing environmental comfort in the building including thermal comfort and indoor air quality. Traditionally, the mechanical systems in the building are the most energy intensive. Innovative en
Electrical Engineer	The Electrical Engineer is responsible for coordinating all the electrical systems in the building. The electrical engineer can be helpful in increasing the efficiency of the electrical system through lighting and motion detectors.
Plumbing Engineer	In a traditional building the plumbing engineer coordinates all of the pipes in the building. In a green building the plumbing engineer may be asked to examine means for increasing the efficiency of the system, recycling water strategies, and rainwater c
Lighting Specialist	Most architects only hire lighting specialists for specialty building types like performance halls. Lighting specialists can be very helpful in minimizing the use of electricity through the careful addition of daylighting. As well, the lighting speciali
Specifications Writer	Often considered an after thought the specifications writer is crucial in producing a sustainable building. The spec writer can reduce the buildings footprint by specifying local materials and materials with low embodied energy.

Figure 2.1—5 Design Professionals

2.1.2.4 The Design Process

In the United States, professionals design buildings in a familiar, refined process. Decisions made during this process impact the environment. It is not normally a part of the building design process to justify each decision against the range of possible alternatives (Manning, 1995) and the environmental impact of those decisions. Design process decisions

are not taken in isolation. Instead, decisions are made in conjunction with all the design consultants, although the most crucial decisions – related to orientation, built form, building fabric and materials are typically taken by the architect (Gangemi et al., 2000). BridgeGreen recognizes the difficulty in changing the current design process and chooses to work within it. In fact, the first thing the user does is selects the phase of interest. Strategies for sustainable design become more specific along the design process. Initially strategies may apply to multiple building systems, design professionals, and environmental impacts, but as the design progresses, strategies will be more specific. For instance, in pre-design a strategy may be to use environmentally preferable materials. A strategy in construction documents will list using wood from a certified forest as a strategy for the superstructure. (See Figure 2.1-7.)

Project Phase	
Conceptual Design	In conceptual design a project is just beginning to be realized. Many decisions made at the conceptual design phase, such as where to build, have large environmental implications
Pre-Design	During Pre-design it has been established that there will be a project. Most likely the site is chosen and the program is being developed. Research in terms of building performance goals and site conditions are being explored. The team at this point is being formuleated based upon the goals
Schematic Design	During Schematic Design the basic building form, adjancancies and systems are determined.
Design Development	Design Development is a refinement of the Schematic Design. More thought is given as to how the building will be built, and what things really look like.
Construction Documents	During construction documentations, the team's task is to produce a set of drawings so the contractor can build the building. This means every detail is worked out and documented. In addition a complete document of specifications is provided to occompany to drawings.
Bid/ Award/ Code Approval	In some cases the project is put to bid for general contractors and sub contractors. It is preferable if the general contractor is brought into the project as early as possible. If the project is bid, it is crucial for sustainability goals and specifications to be clear.
Construction/ Administration	The General Contractor and the architect are the main players during construction. It is crucial during this stage that both remember the project's goals and ensure the building is built to specifications.
Occupancy	In order for the building to operate as intended it is important for the occupants to understand how to use it. More energy and materials go into occupancy of the building than the intial construction.
Demolition/ Reuse/ Disassmebly	This phase is often forgotten and neglected. Consideration of the building's end of life is crucial to sustainabilty. The building can either be demolished and sent to the landfill or more preferably reused or disassembled and rebuilt elsewhere.

Figure 2.1—6 Project Phases

2.1.3 Strategies

BridgeGreen suggests a number of design strategies based on the selected criteria. It uses a logic table to link each strategy to the environmental impacts, design professionals, building systems, and design phases. (See Figure 2.1-8.)

STRATEGIES BY PHASE	ENVIRONMENTAL IMPACT: global warming	environmental performance	acidification	eutrophication	natural resource depletion	solid waste	ecological toxicity	human toxicity	ozone depletion	smog	BUILDING SYSTEM: site	sub structure	super structure	skin	environmental systems	electrical	plumbing	acoustics	interior fitout	lighting	DESIGN PROFESSIONAL: owner	architect	general contractor	geotechnical engineer	landscape architect	civil engineer	structural engineer	mechanical engineer	electrical engineer	plumbing engineer	lighting engineer	acoustics engineer	specialty
SD																																	
Consider holding an environmental design charrette to solicit input on the needs and concerns of the community	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1
Review design criteria carefully, including temperature and humidity requirements, ventilation rates, and occupancy schedules	1	1	1	1	1	1	1	1	1	1				1	1	1	1	1	1	1	1	1		1	1				1				
Gather information on the local climate	1	1	1	1	1	1	1	1	1	1	1			1	1					1	1	1			1								
Analyze site microclimate to identify features that will impact energy design	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1			1			1					
Explore potential for utility rebates for energy efficiency and/ or renewable energy	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1				1	1	1			1			1					
Research performance benchmarks	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1						1			1		
Select energy analysis tools, including computer analysis and physical models	1	1	1	1	1	1	1	1	1	1		1	1	1	1					1	1	1	1				1	1	1	1	1	1	1
Develop a base case energy model	1	1	1	1	1	1	1	1	1	1		1	1	1	1					1	1	1						1					
Estimate water use requirements	1	1	1	1	1	1	1	1	1	1						1				1	1								1				
Test quality of potable water sources	1	1	1	1	1	1	1	1	1	1						1				1	1								1				
Identify local water and sewer network, and rate structures	1	1	1	1	1	1	1	1	1	1	1					1				1	1	1				1			1				

Figure 2.1—7 Strategies Logic Table

There are countless strategies for greening buildings. Strategies become particular to specific buildings. They are dependent upon many factors including building size, type, and location. BridgeGreen does not specify a combination of strategies for a building, and using BridgeGreen strategies does not inherently suggest the building will be green. It is possible, in fact, that strategies will contradict each other. The intent is for strategies to guide users towards

resources. They are not answers in themselves, but means to ask the right questions. The resources should help determine whether a specific strategy is appropriate for a particular building project. BridgeGreen will update its strategies frequently. In addition, BridgeGreen users may suggest additional strategies.

2.1.4 Resources

Professor of environmental science at the University of Amsterdam Lucas Reijinders and verify, "There are many instruments or tools to improve building environmentally that may be generalized (1999). Useful tools are green building requirements sometimes based by law (mandatory), private, voluntary and contractual origin. Other tools provide guidance. There are environmental preference lists for building materials and building components, eco-labeling schemes for building products, and life cycle analysis-based tools for the environmental improvement of building components. In addition, there are manuals for sustainable buildings, checklists for suggesting environmentally improved alternatives for current practice, and environmental scoring systems. Blueprints, often in the form of demonstration projects, exist that set the standard for an environmentally improved building. Smaller or larger parts thereof may be incorporated in actual buildings. As well, there are numerous computer-based tools for guidance in improving part or complete buildings (Reijnders and Roekel, 1999.) While BridgeGreen's list of resources is not complete, it aims to be the most comprehensive accumulation of resources. The resources are both broad and specific. A general strategy in pre-design may point the user towards a book, while a more specific strategy in construction documents may direct the user to specific pages in that book. Because of the exponential growth of resources and changing information, BridgeGreen will update its resource list monthly. Similarly to strategies, users may suggest additional resources to include in BridgeGreen.

2.1.5 BridgeGreen

BridgeGreen is located at http://www.BridgeGreen.com. Its logo is an image of a straw suspension bridge built in the height of the Incan Empire. The bridge, still in use today, spans the Rio Apurimac, and embodies sustainable principles. (See Figure 2.1-9.) Clicking anywhere on the first screen brings the user to the introductory page. It contains information about the project, access to a copy of this thesis document and the PowerPoint presentation that supports it. The page also has an email link for visitors to comment on the tool. There are also simple directions on how to use BridgeGreen. (See Figure 2.1-10.)

Figure 2.1—8 Logo

TO BEGIN:
1) Click on the icon above
2) Select a design phase
3) Select one or more criteria from the matrix.
4) Submit criteria
5) Review and select strategies
6) Submit selected strategies
7) Review tools.
8) Return to matrix or output data

BridgeGreen was developed as part of a Masters of Science in Architecture Studies thesis, at the Massachusetts Institute of Technology, in the Spring of 2003. The thesis identifies a disconnect between design professionals and resources for environmentally, socially, and economically responsive architecture. This tool is an attempt to bridge that disconnect.

BridgeGreen connects desired resources to design professionals at appropriate phases in the design process. It does this by asking the user to select criteria in a matrix of project phases, design professionals, building systems, and environmental impacts.

BridgeGreen suggests a number of design strategies, based on the selected criteria. Each strategy is inked to one or more resource for environmentally, socially, and responsive architecture.

BridgeGreen strives to connect resources with design professionals so that they can make informed decisions during the design process relative to environmental impact. An increase in informed decisions will inevitably decrease the negative impact buildings have on the environment. There are indeed numerous obstacles to green design. This tool is just one of many methods in overcoming the barriers.

BridgeGreen is interactive. Strategies and resources for green building are increasing exponentially. A major component of the tool is the opportunity for users to suggest additional tools and strategies. The tool's success depends on this interaction.

Cick here for a copy of the thesis.
Click here to email comments.

Meredith Elbaum SMArchS 2003
Thesis Advisor: Professor John E. Fernandez
Readers: Professor John Ochsendorf and William Porter

BridgeGreen thanks Bryson Hyte for help in developing it

Figure 2.1—9 Introductory Page

Clicking on the logo directs the user to the following page. The next page asks the user to

select a project phase. Project phases may vary slightly from office to office and even project to project and may be completely different from other countries' prescribed project phases. In anticipation of differing nomenclature, the tool provides definitions of each phase. The user then is able to equate phases and find relative information. The phases are described elsewhere in this document. [See Figure.]

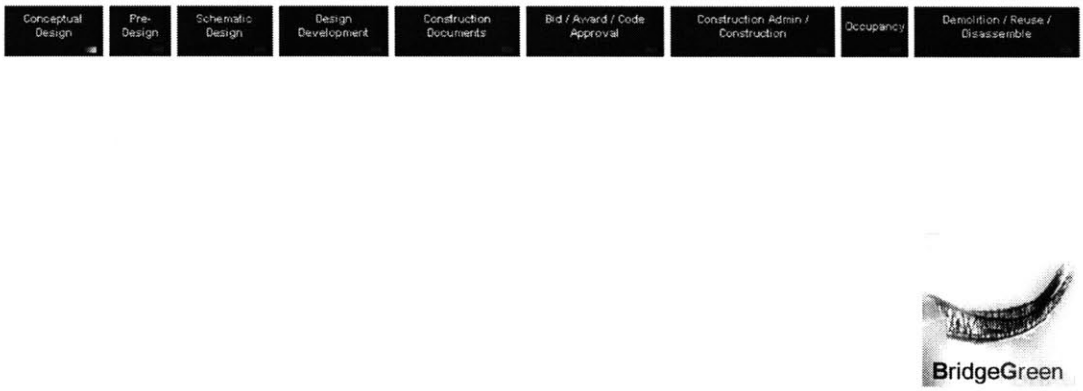


Figure 2.1—10 Phases

Once the user chooses a phase, a trace of the selection remains on screen. At any point, the user can opt to switch phases. The user submits the selected phase and BridgeGreen presents a matrix of environmental impacts, design professional and building system. For clarity, scrolling over a colored box in each block presents a text block defining the block's title. For instance, scrolling over the red box in the Global Warming block will present a text box defining Global warming. The user selects one or more criteria. The more criteria

selected, clearly the more refined the results. When satisfied with the criteria selected, the user selects the Submit Criteria button (See Figure 2.1-12.)

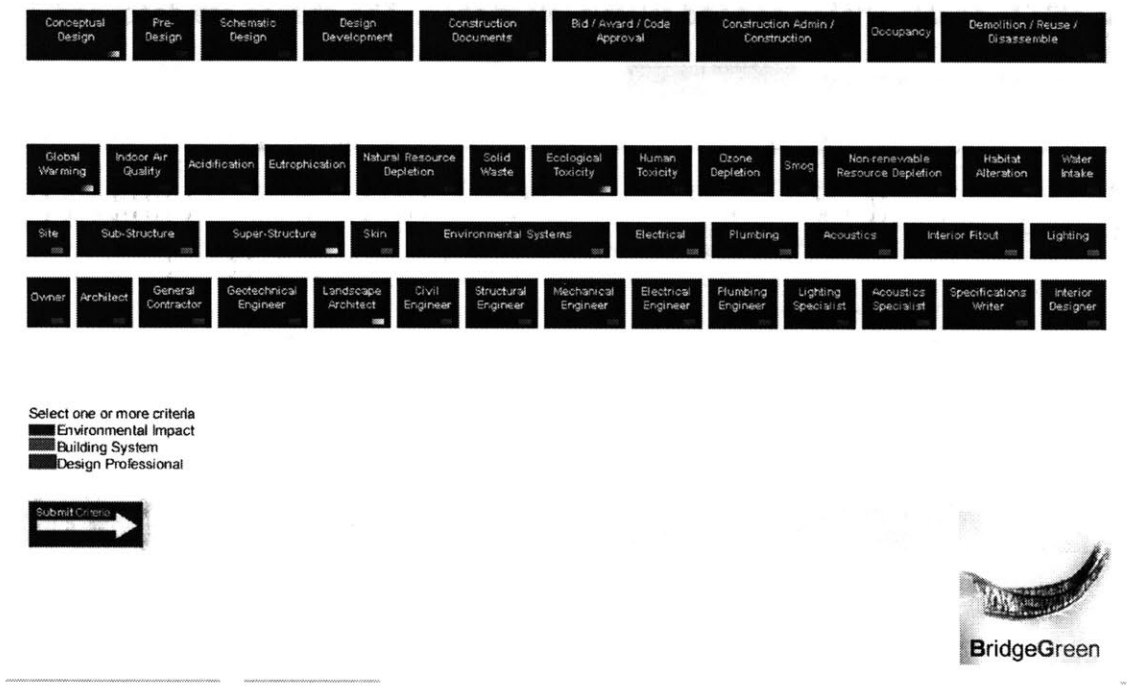


Figure 2.1—11 The Matrix

The tool then finds strategies associated with the criteria. At any point, the user may change the criteria selection. A trace of the blocks chosen remains on screen. The user may change the selection at any point. (See Figure 2.1-13.)

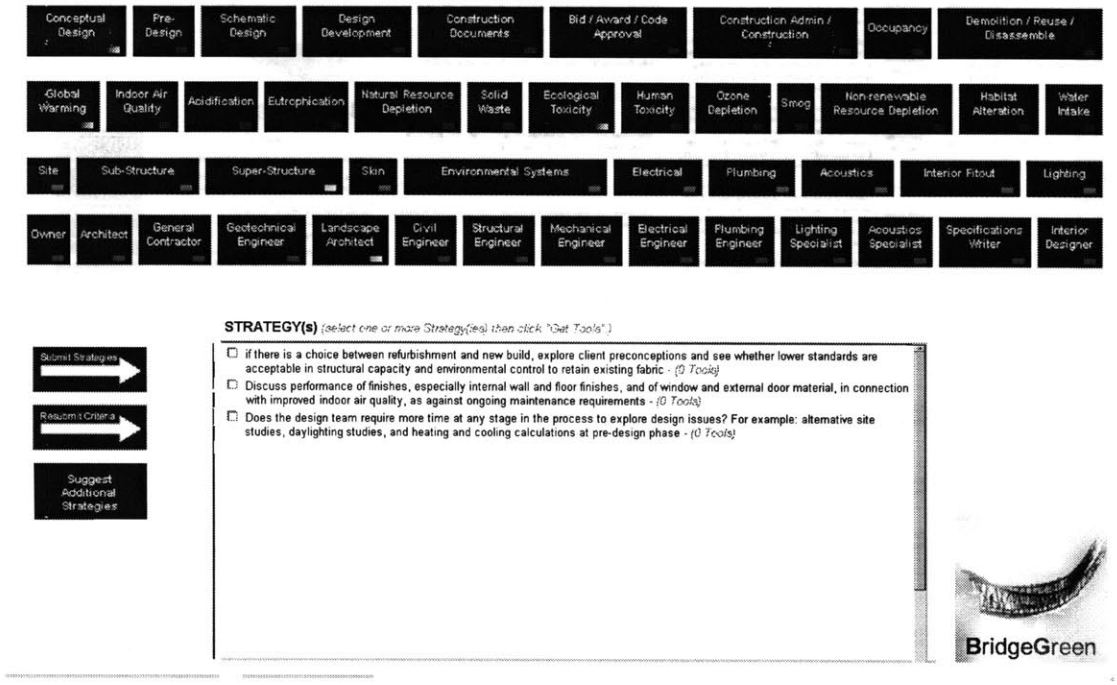
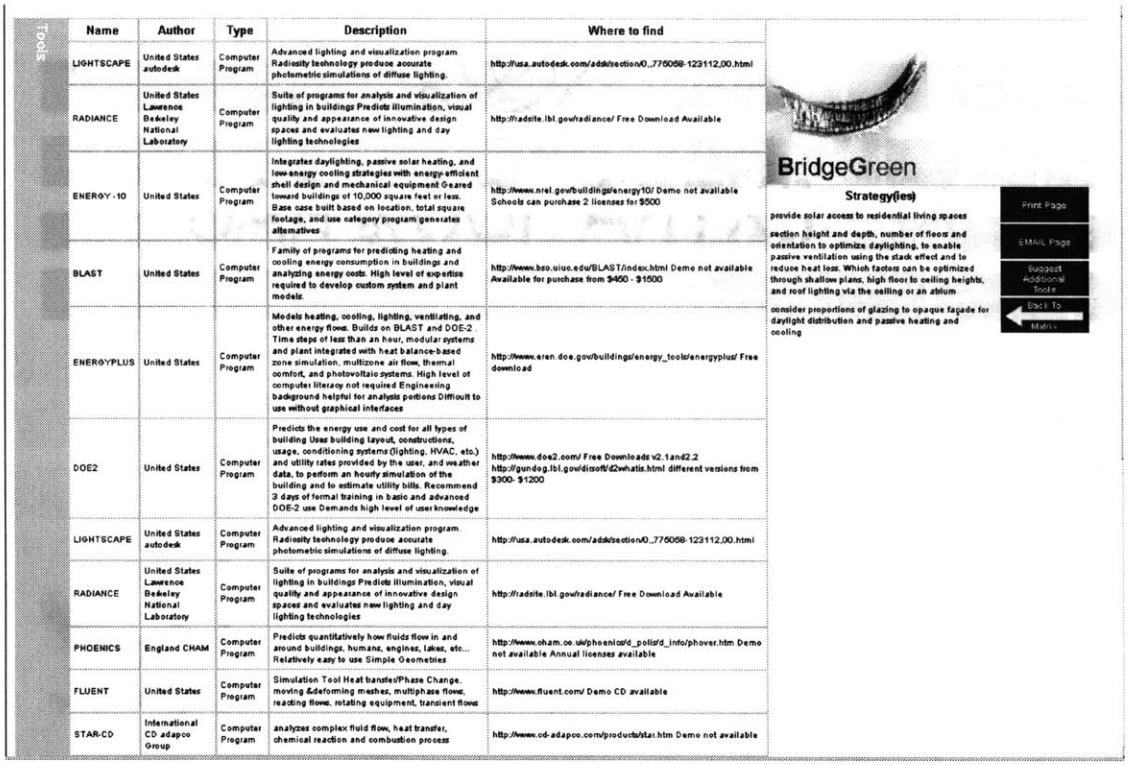


Figure 2.1—12 Strategies

An added feature is the ability to suggest additional strategies. Clicking the Suggest Additional Strategy button brings up an email box. Hitting Send forwards the suggestion to the webmaster for considered inclusion. Presented with a list of strategies, the user selects those of interest. After selecting one or more strategies, the user clicks Submit Strategies and is presented with a list of resources. BridgeGreen names each resource, identifies the author, classifies it, provides a brief description and explains how to access it. At this point, the user can print the page or send it via email and suggest additional resources. The user then may return to the matrix or quit. (See Figure 2.1-14.)



Tools

Name	Author	Type	Description	Where to find
LIGHTSCAPE	United States autodesk	Computer Program	Advanced lighting and visualization program. Radiosity technology produce accurate photometric simulations of diffuse lighting.	http://usa.autodesk.com/adsk/section/0,,776058-123112,00.html
RADIANCE	United States Lawrence Berkeley National Laboratory	Computer Program	Suite of programs for analysis and visualization of lighting in buildings Predicts illumination, visual quality and appearance of innovative design spaces and evaluates new lighting and day lighting technologies	http://radsite.lbl.gov/radiance/ Free Download Available
ENERGY-10	United States	Computer Program	Integrates daylighting, passive solar heating, and low-energy cooling strategies with energy-efficient shell design and mechanical equipment Geared toward buildings of 10,000 square feet or less. Base case built based on location, total square footage, and use category program generates alternatives	http://www.nrel.gov/buildings/energy10/ Demo not available Schools can purchase 2 licenses for $500
BLAST	United States	Computer Program	Family of programs for predicting heating and cooling energy consumption in buildings and analyzing energy costs. High level of expertise required to develop custom system and plant models.	http://www.bso.uiuc.edu/BLAST/index.html Demo not available Available for purchase from $400 - $1500
ENERGYPLUS	United States	Computer Program	Models heating, cooling, lighting, ventilating, and other energy flows. Builds on BLAST and DOE-2. Time steps of less than an hour, modular systems and plant integrated with heat balance-based zone simulation, multizone air flow, thermal comfort, and photovoltaic systems. High level of computer literacy not required Engineering background helpful for analysis portions Difficult to use without graphical interfaces	http://www.eren.doe.gov/buildings/energy_tools/energyplus/ Free download
DOE2	United States	Computer Program	Predicts the energy use and cost for all types of building. Uses building layout, constructions, usage, conditioning systems (lighting, HVAC, etc.) and utility rates provided by the user, and weather data, to perform an hourly simulation of the building and to estimate utility bills. Recommend 3 days of formal training in basic and advanced DOE-2 use Demands high level of user knowledge	http://www.doe2.com/ Free Downloads v2.1and2.2 http://gundog.lbl.gov/dirsoft/d2whatis.html different versions from $300- $1200
LIGHTSCAPE	United States autodesk	Computer Program	Advanced lighting and visualization program. Radiosity technology produce accurate photometric simulations of diffuse lighting.	http://usa.autodesk.com/adsk/section/0,,776058-123112,00.html
RADIANCE	United States Lawrence Berkeley National Laboratory	Computer Program	Suite of programs for analysis and visualization of lighting in buildings Predicts illumination, visual quality and appearance of innovative design spaces and evaluates new lighting and day lighting technologies	http://radsite.lbl.gov/radiance/ Free Download Available
PHOENICS	England CHAM	Computer Program	Predicts quantitatively how fluids flow in and around buildings, humans, engines, lakes, etc... Relatively easy to use Simple Geometries	http://www.cham.co.uk/phoenics/d_polis/d_info/phover.htm Demo not available Annual licenses available
FLUENT	United States	Computer Program	Simulation Tool Heat transfer/Phase Change, moving &deforming meshes, multiphase flows, reacting flows, rotating equipment, transient flows	http://www.fluent.com/ Demo CD available
STAR-CD	International CD adapco Group	Computer Program	analyzes complex fluid flow, heat transfer, chemical reaction and combustion process	http://www.cd-adapco.com/products/star.htm Demo not available

Figure 2.1—13 Tools

The logic rules below clarify this process.

Rules

- Each "Phase" contains one or more "Strategies"
- Each "Strategy" can be related to an "Environmental Impact" criteria
- Each "Strategy" can be related to a "Building System" criteria
- Each "Strategy" can be related to a "Design Professional" criteria
- Each "Strategy" can be related to a "Resource"
- Each "Tool" has "Attributes" such as Name, Author, Description, Type, and Where to Find.
- User selects ONE "Phase"
- User **MAY** select **ONE OR MORE** "Environmental Impact(s)"
- User **MAY** select **ONE OR MORE** "Building System"
- User **MAY** select **ONE OR MORE** "Design Professional"
- User **MUST** select **ONE OR MORE** of the above criteria
- User **SUBMITS** criteria
    - System identifies "Strategies" related to "Phase"
        - If a "Strategy" is related to more than one criterion, the "Strategy" is only returned once
        - System identifies related "Resource(s)" per "Strategy"
        - If a "Resource" is related to more than one "Strategy", the "Resourcel" is only returned once

    - System renders User's criteria, "Resource(s)" and related "Attributes", and "Strategies"
- User can **PRINT** results
- User can **EMAIL** results
- User can **SUGGEST** additional "Resource(s)"
- User can **RETURN TO MATRIX SELECTION**
- User can **END** session

2.1.6 Why Web-Based

BridgeGreen is an interactive Web-based tool. There are many problems associated with a Web-based tool. First, it assumes people have connection to the Internet. This is especially troublesome considering the social implications. While the product may be free, it necessitates the investment in a computer. Not all design professionals have Internet access especially in developing countries. Fortunately, public access to the Internet in libraries is becoming more readily available. It also requires compatibility of systems. This is becoming less of a problem. At the time this thesis was written, BridgeGreen was operating only on Microsoft's Internet Explorer. If BridgeGreen were a printed manual, instead of Web-based, after publication, paper-based material is essentially complete. BridgeGreen will require constant updating. This is both an obvious advantage and disadvantage. There also inevitably will be technical problems that arise, which require time and attention from technical support. Another and important drawback for consideration for Web-based tools is that users can get lost in a maze of external references (hyperlinks). Commonly known as hypertext-related disorientation and cognitive overload, this occurs when there is so much information, that users get lost in its depth. They may forget what they were initially looking for and get frustrated with the amount of information.

While there are disadvantages to designing BridgeGreen as a Web-based tool, the advantages significantly outweigh them. Strategies and resources for green building are increasing exponentially. "Nowadays, the related information and technologies about energy efficiency and renewable energy are growing very fast and getting more complex"(Hui and

Cheung, 1999). The Internet and World Wide Web (WWW) can be an effective medium for the delivery of quality education and training for environmentally, socially, and economically responsive architecture because of its flexibility, timeliness, and breadth of access (Hui and Cheung, 151.) The WWW as a network infrastructure has the great advantage of flexibility and low cost. Administrators can readily update information as needed without the costs of reprinting the material each year. Users, in this case, always access the latest version with up to date information. Textbooks are static and tend to become obsolete soon after publication. Web materials are dynamic and allow for easy updating and fast dissemination. In the building research field, access to recent research and data over the Internet is getting increasingly important.

Another advantage is that people with Web access may come across this free product by chance. It is more likely for someone to find BridgeGreen on the Web than in a library or bookstore. In addition, BridgeGreen saves time. It does not require the person spend the time to order or buy a copy. It lets multiple people in one office have access to the information at once without the office purchasing numerous copies. BridgeGreen gives users direct access to resources. In some cases, resources are literally a click away. In a print version, it would take much more effort on the users part to access information. Also a Web-based tool focused on environmental, social, and economic issues, BridgeGreen negates the negative impacts associated with printing and distributing.

A further benefit of BridgeGreen as a Web-based tool is that its multimedia nature provides an environment richer and more interactive than traditional paper-based alternatives (Hui and Cheung, 1999). Text, graphics, audio, and video accommodate different learning styles and provide approaches for both visual and auditory learners. In addition, as an online tool, BridgeGreen links to websites throughout the world, and creates a rich environment that combines both local and global resources. There are already a number of systems on the WWW designed for information management, education and networking for energy efficiency

and renewable energy, such as CREST, ISES and USDOE (Hui and Cheung, 1999). BridgeGreen links directly to these existing resources.

The most important advantage of BridgeGreen as Web-based tool is that the users suggest additional resources and strategies. BridgeGreen, then, is a living system where its users are also its authors. This could not occur with a non Web-based tool. The tool's success depends on this interaction. Future development will focus on this aspect.

2.1.7 Distinctions

With so many tools available on the market, the question becomes how will this tool avoid becoming yet another tool. The best way to do this is word of mouth. In order for people to spread this word, the tool must be useful, simple to use and content rich. It should be targeted and marketed as *the place* to find resources for green design. BridgeGreen is visually appealing, valuable, fun, current, easy to find and use, intuitive, interactive and responsive to its users. It is organized in ways that are meaningful to the users so they can navigate through the site without getting lost and frustrated. BridgeGreen's content is in the language of its users and its queries retrieve meaningful results. The greatest use of the WWW is informal learning through browsing. People access and learn from information made available by a whole host of organizations and individuals within a noncredit-granting structure (Hui and Cheung, 1999). BridgeGreen takes advantage of this. These characteristics of a successful web page are in line with those suggested by Hui and Cheung's 1999 article in *Solar Energy*, "Developing a web-based learning environment for building energy efficiency and solar design in Hong Kong."

2.1.8 Further Development

At the submission of this thesis, BridgeGreen is live at http://www.BridgeGreen.com. But, there are plans to continue to develop BridgeGreen. The first objective is to enhance its user interface for clarity and graphic intensity. As is, BridgeGreen, does not have enough directional cues. The text is too small and the buttons are difficult to see. Because its target

users are design professionals, it is even more important for the tool to be graphically clear and appealing. Also, for the tool to be useful, it requires the addition of strategies and associated resources. The current list is brief and incomprehensive. These two concerns, user interface and content, must be addressed before anything else.

After this, there are many other development opportunities. In order to ensure up-to-date content, there may be an automated search for additional resources. Artificial intelligence software could check various sites frequently for new resources. There would need to be a means to check the findings before inclusion on BridgeGreen. Another development opportunity bases itself on the idea that strategies are specific. It is important to refine searches as much as possible to limit the number of resulting strategies. Identifying building size, building type and building location is a first step. There should also be a function for users to search for specific resources or strategies. Users may know of a resource and want to know where to find it. They should be able to do this without navigating the entire site. Currently, users can only look at one phase per search. It may be valuable in the future to compare strategies and tools for different phases. For example, a project coordinator may want to see which strategies overlap for different design professionals. BridgeGreen primarily focuses on buildings in the United States. For future development, it will be important to include more global strategies and resources and have the tool be multilingual. In addition, BridgeGreen lacks many strategies and resources focused on economic and social issues. This is an indicator of sustainability in general. The developers may choose to focus more on these aspects in the future. Another problem with sustainability and green building assessment is the lack of inherent weighting. BridgeGreen falls victim to this as well. In the future, it would be important to establish a hierarchy of criteria selection. For example, BridgeGreen will tell the user which design professional is more important to target at a particular phase or for a particular building system.

As indicated earlier, a major advantage of BridgeGreen is that its users are its authors. Development should exploit this. Users will have the opportunity to rate and comment on

resources and strategies. BridgeGreen can host a discussion group specifically focused on resources and tools. Also, in order to provide users with the best information, it will be important to track user history.

Another consideration for BridgeGreen is to offer customized software. While users may not benefit from the interactive nature of BridgeGreen, it may be possible to customize the software for specific users. The nomenclature of the matrix then would be specific to the user and the strategies and resources could be limited to the users' needs.

While BridgeGreen's goal is to disseminate resources and not to earn a profit, it will take funding to maintain it. Initially it will be difficult to charge people for using the site, although there is potential for advertisers. Targets would be product representatives (Interface, Dupont, American Hydrotech), online retailers, periodicals looking for subscribers, computer tools, and member organizations. Advertisers would be interested in monitoring hits on the site and identifying which strategies and resources are hit most often. The disadvantage of using advertisers to support this tool is the potential to create biases towards particular tools and resources. This is critical to avoid. Building Green, *EBN's* parent organization, began as a free informational website. Initially it posted *EBN* articles on the website at no cost (BuildingGreen, 2003). After a few years, people became dependent on the site for information. Building Green started charging for access to the articles. BridgeGreen could follow the same model. There may be opportunities for third-party funding. The Department of Energy, the American Institute of Architects, the United States Green Building Council, and Building Research Establishment, among others, may be interested in funding the tool for further development.

3.0 Conclusion

The American Institute of Architects' Code of Ethics and Professional Conduct states, "Members should maintain and advance their knowledge of the art and science of architecture, respect the body of architectural accomplishment, contribute to its growth, thoughtfully consider

the social and environmental impact of their professional activities, and exercise learned and uncompromised professional judgment"(AIA, 2003). According to a member survey conducted in 2001 by the United States Green Building Council, USGBC members are generally optimistic about the future of the green building industry. Almost 58 percent envisioned slow, but steady, growth in the industry and 32 percent see rapid growth. Only three percent said the situation would remain unchanged from today (http://www.usgbc.org.) American architects will have to work hard to achieve sustainability and further to reach beyond. It will entail a process of learning and sharing uncommon in traditional architecture. They will redefine goals and methods. If successful, architects will play a crucial role in minimizing not only the building industry's ecological footprint, but also the environmental impact of society at large.

4.0 Appendix

4.1 Strategies

PHASE	global warming	environmental performance	acidification	eutrophication	natural resource depletion	solid waste	ecological toxicity	human toxicity	ozone depletion	smog	site	sub structure	super structure	skin	environmental systems	electrical	plumbing	acoustics	interior fitout	lighting	owner	architect	general contractor	geotechnical engineer	landscape architect	civil engineer	structural engineer	mechanical engineer	electrical engineer	plumbing engineer	lighting specialist	acoustics specialist	specifications writer	interior designer
	ENVIRONMENTAL IMPACT										BUILDING SYSTEM										DESIGN PROFESSIONAL													
conceptual design																																		
Seek out planners, architects, and landscape architects experiences with ecological urban and community planning, site planning, and landscape design	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1												
Establish energy design team - Consider use of specialty consultants for energy analysis, lighting, and daylighting	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1												
Suggest that the client include future building operator responsible for energy management on the team, as a participant in the design process	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1												
Seek out plumbing engineers, HVAC engineers, and civil engineers experienced with water conservation and reuse, and natural wastewater treatment systems	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1												
Consider enlisting a specialty consultant to evaluate the feasibility of on-site natural wastewater treatment, and to design the system if appropriate	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1												
Recommend that the client include future building operators and maintenance staff on the design team, and that one of them be designated the "indoor air quality manager"	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1												
Consider hiring an IAQ consultant	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1												
Seek out architects, engineers, landscape architects, and interior designers who can evaluate environmental and health impacts of the building materials and systems they specify over their full life cycle - consider hiring a consultant to help with their task	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1												
identify green design as an issue to be considered	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1												

agree environmental performance targets for the building	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1	1 1	
prefer brownfield sites to greenfield sites	1 1 1 1 1 1 1 1 1 1	1	1 1	
will the client actively manage the environmental control systems on a day to day basis	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1	1 1	
if there is a choice between refurbishment and new build, explore client preconceptions and see whether lower standards are acceptable in structural capacity and environmental control to retain existing fabric	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1	1 1 1	1 1 1 1 1 1 1 1
review and agree design comfort standards with a view to reducing energy demand	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1	1 1	
explain the need for climatic data on the site: macro-climate; material from meteorological stations and micro-climate: survey work may be necessary	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1	1 1	
use pattern (diurnal, weekly and seasonal) affect environmental requirements and choice of structure and systems. Is the building used intermittently or regularly? Are there long holiday periods? Construct a use profile of the building: occupants and activities at different times of day and week.	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1	1 1	
what green expertise does the architect have? Don't pretend expert knowledge without dedication training and/or substantial experience	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1	1 1	
explain that the subject is not yet definitively research and that much remains to be done in researching green urban planning and materials for example	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1	1 1	
do you recommend that environmental, daylighting or energy consultants be appointed? Who will pay for these?	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1	1 1	
Can the cost be offset against 'normal' consultants? Does the client intend to nominate consultants? If so do they have the green expertise or do they need to be supplemented by specialists?	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1	1 1	
Ensure that the scope of appointments includes the requisite environmental advice	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1	1 1	
Explain the possibilities of passive measures: their contribution to performance	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1	1 1 1	1
Can the client use sunspaces if provided?	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1	1 1 1	1

How does the client feel about draught lobbies? About zoning the plan?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1			
Are weather compensating controls justified?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1			
Will the client use 7-day programmable controls?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1			
Would the client consider a CHP installation?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1			
Will the client countenance passive cooling measures if these are judged useful?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1			
How precise is the level of environmental control required? Can temperatures go above comfort levels, say, 5 days per year? Or never?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1			
Is daylight maximization a desirable goal?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1						1
Will the client pay for passive infrared switching? Individual light switching? For photoelectric override of active systems?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				1		
Will the occupant manually operated trickle vents in windows?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1			
Is passive stack ventilation an option?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1			
In what area is mechanically assisted ventilation required?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1			
Identify the possibilities of heat exchangers, discuss capital against life cycle costs	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1			
Would the client pay for low-water WC cisterns and lavatory controls, spry traps?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	
Discuss disposing of surface water run-off on site, and advise on the need for treating run-off from car parks	1	1	1	1	1	1	1	1	1	1	1				1		1				1	1		1	1				
Is composting of domestic refuse on site acceptable?	1	1	1	1	1	1	1	1	1	1	1										1	1	1	1	1				
What provision might be made for recycling paper, of packaging? Need for extra storage space?	1	1	1	1	1	1	1	1	1	1	1								1		1	1							
Identify existing vegetation to be conserved and discuss how this affects the design	1	1	1	1	1	1	1	1	1	1	1			1	1		1		1		1	1	1	1	1				
Discuss the provision of sheltered and secure bicycle storage	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1							
Explore the possibility of alternative structural systems and materials, which might influence load-bearing capacity	1	1	1	1	1	1	1	1	1	1		1	1	1	1			1	1		1	1	1		1				

Discuss performance of finishes, especially internal wall and floor finishes, and of window and external door material, in connection with improved indoor air quality, as against ongoing maintenance requirements	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1 1 1 1
To what extent is the client concerned with life-cycle issues? Explain life-cycle costing: investigate the client's intention for the building: short or long term investment? It is not yet easy to demonstrate that green design increases capital value. It may be necessary to benchmark the building cost against that of comparable non-sustainable buildings	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1	1 1
Try to obtain agreement that a measure of life-cycle costing may be factored into all design and specification decisions	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1	1 1
Does the design team require more time at any stage in the process to explore design issues? For example: alternative site studies, daylighting studies, and heating and cooling calculations at pre-design phase	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1 1 1 1
Discuss the steps needed to select the contractor and how the design will impact on the construction process	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1	1 1 1
			2 6 7 3 4 4 4 3 2

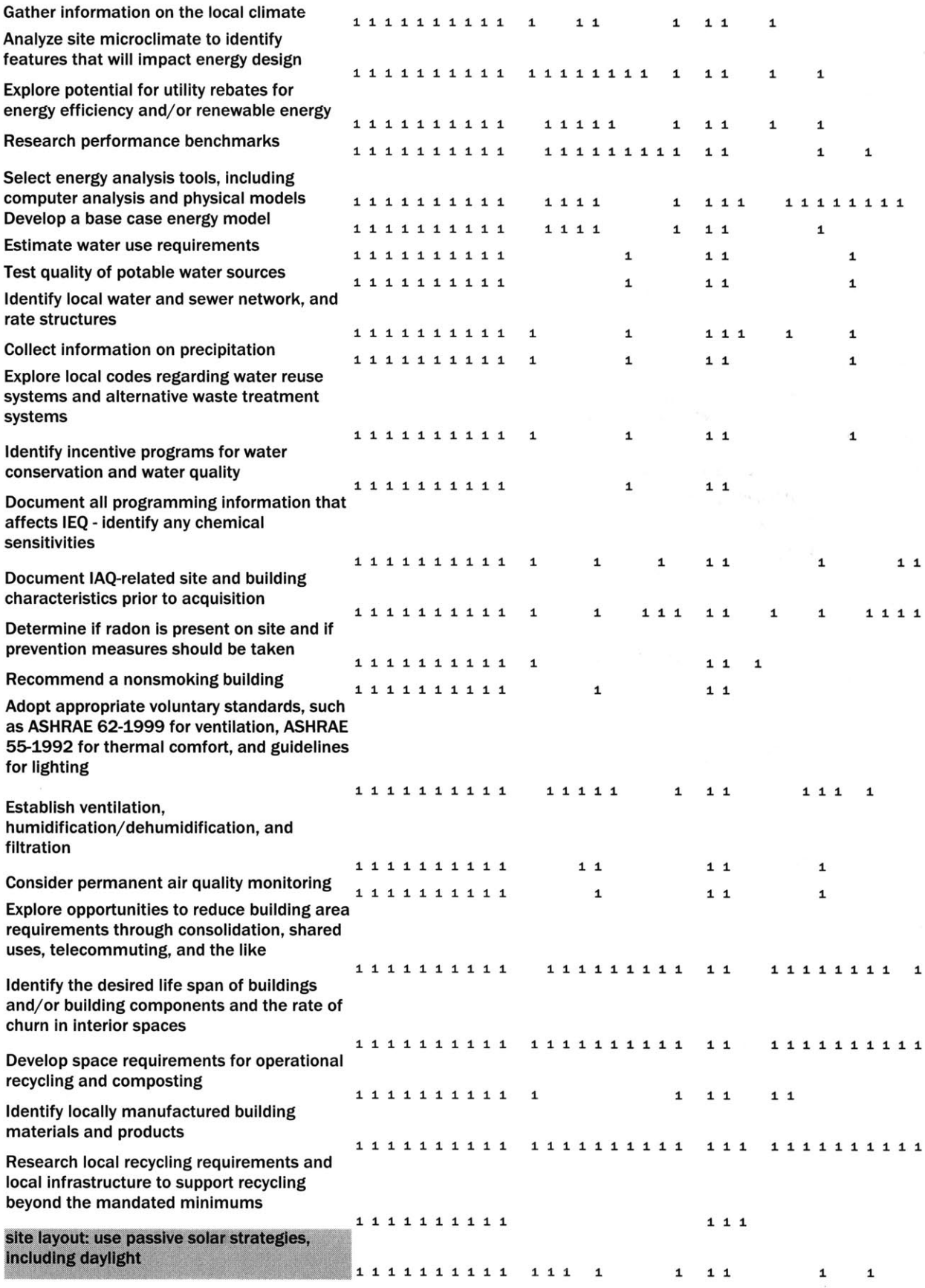
pre-design			
educate the team about the importance of the relationship between the built and natural environments, and the impact that individual facilities have on their larger communities and natural systems	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1 1 1 1
Make a commitment to develop regional and community planning projects to promote livable cities, based on the Ahwahnee Principles	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1 1 1 1
Make a commitment to create positive connections between the new/renovated facility and its community	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1 1 1 1
Place priority on development of an urban infill site and/or rehabilitation of an existing building	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1	1 1 1 1 1 1 1 1 1 1 1 1 1
Encourage the owner to develop a master plan for the site, to plan for future growth and protect natural site features	1 1 1 1 1 1 1 1 1 1	1	1 1 1 1

Educate the team about the importance of design optimization instead of code minimum design	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Education the team about the various methods for accessing life cycle costs, and select the preferred method	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Identify energy performance goals and develop a strategy for meeting them	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1	1	1				1	1	1		1		
Make a commitment to commission the building	1	1	1	1	1	1	1	1	1	1									1		1	1	1					1					
Make a commitment to engage in future energy management	1	1	1	1	1	1	1	1	1	1					1				1		1	1						1	1		1		
Consider participation in voluntary incentive programs	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Educate the team about the importance of water conservation, water reuse opportunities, and the ecological value of natural wastewater treatment systems	1	1	1	1	1	1	1	1	1	1	1						1				1	1	1		1	1		1		1			
Define project goals for water as a team - include consideration of water conservation, water reuse, and natural wastewater treatment	1	1	1	1	1	1	1	1	1	1	1						1				1	1	1		1	1		1		1			
Recommend that the owner plan for future water management	1	1	1	1	1	1	1	1	1	1	1						1				1	1	1		1	1		1		1			
Educate the team about the importance of indoor environmental quality (IEQ) including lighting and acoustics, thermal comfort, access to daylight, connection to nature, and good indoor air quality (IAQ)	1	1	1	1	1	1	1	1	1	1				1	1			1	1	1	1	1	1					1			1	1	1
Educate the team about the cost and schedule implications of design strategies to protect IAQ	1	1	1	1	1	1	1	1	1	1				1	1			1	1	1	1	1	1					1			1	1	1
Develop IEQ goals, including performance objectives for lighting, acoustics, thermal comfort, access to daylight, connection to nature, and IAQ	1	1	1	1	1	1	1	1	1	1				1	1			1	1	1	1	1	1					1			1	1	1
Educate the team about the importance of design flexibility to enhance the longevity of buildings and infrastructure	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Educate the team about the environmental and health impacts of building materials over their full life cycle, from raw materials acquisition to production processes, packaging and shipping, installation and use, and ultimate resource recovery	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1
Consider opportunities to reuse an existing building over new construction	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Make a commitment to consider environmental and health impacts over the full life cycle when selecting materials and products - identify which of these issues is of highest priority for the project, based on the building type and location	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1
Make a commitment to reduce waste and promote recycling - establish and quantify waste reduction goals	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1
analyze sites for sunlight, shelter, and available shading	1	1	1	1	1	1	1	1	1	1	1									1	1	1			1			1			1		
research building type and analyze good practice examples	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
consider what is achievable given cost constraints	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
obtain environmental information about the site	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
examine the environmental impact of alternative strategies	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
examine a number of alternative sites if this option is available	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
incorporate green issues into the feasibility studies report	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

SD

Analyze the regional impacts of the proposed development on water quality and flooding, wetlands, wildlife habitats, and transportation	1	1	1	1	1	1	1	1	1	1	1										1	1		1	1	1							
Study the microclimate, geology, hydrology, and ecology of the site	1	1	1	1	1	1	1	1	1	1	1										1	1		1	1								
Survey existing plants and wildlife on the site	1	1	1	1	1	1	1	1	1	1	1										1	1			1								
Test site for possible contamination	1	1	1	1	1	1	1	1	1	1	1										1	1	1	1	1								
Identify elements of the site that represent cultural and/or historical resources that should be preserved	1	1	1	1	1	1	1	1	1	1	1										1	1			1	1							
Identify existing pedestrian, bicycle, and transit networks in the community	1	1	1	1	1	1	1	1	1	1	1										1	1		1	1								
Research local native plant species and invasive plants to avoid	1	1	1	1	1	1	1	1	1	1	1										1	1		1	1								
Consider holding an environmental design charrette to solicit input on the needs and concerns of the community	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1
Review design criteria carefully, including temperature and humidity requirements, ventilation rates, and occupancy schedules	1	1	1	1	1	1	1	1	1	1				1	1	1	1	1	1	1	1	1		1	1			1					


Gather information on the local climate
Analyze site microclimate to identify features that will impact energy design
Explore potential for utility rebates for energy efficiency and/or renewable energy
Research performance benchmarks
Select energy analysis tools, including computer analysis and physical models
Develop a base case energy model
Estimate water use requirements
Test quality of potable water sources
Identify local water and sewer network, and rate structures
Collect information on precipitation
Explore local codes regarding water reuse systems and alternative waste treatment systems
Identify incentive programs for water conservation and water quality
Document all programming information that affects IEQ - identify any chemical sensitivities
Document IAQ-related site and building characteristics prior to acquisition
Determine if radon is present on site and if prevention measures should be taken
Recommend a nonsmoking building
Adopt appropriate voluntary standards, such as ASHRAE 62-1999 for ventilation, ASHRAE 55-1992 for thermal comfort, and guidelines for lighting
Establish ventilation, humidification/dehumidification, and filtration
Consider permanent air quality monitoring
Explore opportunities to reduce building area requirements through consolidation, shared uses, telecommuting, and the like
Identify the desired life span of buildings and/or building components and the rate of churn in interior spaces
Develop space requirements for operational recycling and composting
Identify locally manufactured building materials and products
Research local recycling requirements and local infrastructure to support recycling beyond the mandated minimums
site layout: use passive solar strategies, including daylight

provide solar access to residential living spaces	1	1	1	1	1	1	1	1	1	1				1					1		1	1					1			1			
use thermal mass to dampen temperature fluctuations	1	1	1	1	1	1	1	1	1	1		1	1	1	1						1	1					1						
maximize daylight penetration using plan and section	1	1	1	1	1	1	1	1	1	1			1	1	1					1	1	1				1	1			1			
consider water supply and waste handling methods	1	1	1	1	1	1	1	1	1	1	1						1				1	1			1				1				
use locally produced material	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
make iterative studies of design concepts to access performance	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
consider room heights for heating , cooling and daylighting	1	1	1	1	1	1	1	1	1	1			1	1	1					1	1	1				1	1			1			
consider thermal mass for building use pattern: intermittent or continuous	1	1	1	1	1	1	1	1	1	1			1	1	1						1	1					1						
optimize proportion and distribution of external envelope openings with heating and lighting in mind	1	1	1	1	1	1	1	1	1	1			1	1	1					1	1	1				1	1			1			
specify design criteria for services	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
calculate predicted building performances and assess against targets	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
protection and use of pre-existing site characteristics: vegetation, landscaping, topography, water; site disposition for insolation, shading and shelter; proportion of hard landscaping for water run-off or conservation; vegetation and shelter; cold air drainage	1	1	1	1	1	1	1	1	1	1	1										1	1			1								
orientation, zoning and general disposition, with impact on energy consumption	1	1	1	1	1	1	1	1	1	1	1																						
section height and depth, number of floors and orientation to optimize daylighting, to enable passive ventilation using the stack effect and to reduce heat loss. Which factors can be optimized through shallow plans, high floor to ceiling heights, and roof lighting via the ceiling or an atrium	1	1	1	1	1	1	1	1	1	1			1	1	1					1	1	1				1	1			1			
broad proportions of fenestration, with effects on daylighting, ventilation, overheating on east, west and south facades, which can be passively controlled by the use of external shading device	1	1	1	1	1	1	1	1	1	1				1	1						1	1				1	1						
structural system (concrete, steel, or timber) and external envelope, and their environmental impact	1	1	1	1	1	1	1	1	1	1		1	1								1	1				1							
Consider layout and orientation of building groups in relation to insolation and overshadowing	1	1	1	1	1	1	1	1	1	1	1										1	1											

Consider size and location of hard surfaces, in relation to desired sunlight and shelter	1	1	1	1	1	1	1	1	1	1	1										1	1		1									
use earth berms and shelter planting to create protected and sheltered areas	1	1	1	1	1	1	1	1	1	1	1										1	1		1									
provide draught lobbies at entrances where necessary	1	1	1	1	1	1	1	1	1	1					1						1	1											
optimize use of daylight in habitable spaces	1	1	1	1	1	1	1	1	1	1										1	1	1								1			
in northern latitudes, zone areas such as sanitary, circulation and storage to the north	1	1	1	1	1	1	1	1	1	1	1				1						1	1					1						
include air flow paths for natural ventilation in plan and section	1	1	1	1	1	1	1	1	1	1	1			1	1						1	1					1						
consider proportions of glazing to opaque façade for daylight distribution and passive heating and cooling	1	1	1	1	1	1	1	1	1	1				1	1					1	1	1					1			1			
control glare and overheating, particularly on east and west facades: consider shading devices (external louvers, setbacks, or blinds)	1	1	1	1	1	1	1	1	1	1				1	1						1	1					1						
consider use of structural thermal inertia to dampen internal temperature fluctuations	1	1	1	1	1	1	1	1	1	1		1	1								1	1				1	1						
consider sustainability and environmental impact of materials, embodied energy, impact on habitats, toxic emissions and ease of recycling or re-use	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
presentations should indicate how environmental principles will be develops at detailed design stage, and how proposals will be evaluated, with maximum use of passive systems	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
consider combined heat and power to reduce primary energy use	1	1	1	1	1	1	1	1	1	1					1	1					1	1	1				1						
provide outline illustration of environmental performance, particularly through plan and section diagrams for passive and active energy flows	1	1	1	1	1	1	1	1	1	1					1						1	1					1						
Consider factoring environmental and life cycle cost into initial cost estimates	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Design for re-cycling	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
consult about innovative propositions for fresh water supply, rain disposal or reuse, gray and black water disposal	1	1	1	1	1	1	1	1	1	1	1						1				1	1							1				
discuss advantages of tariffs for low consumption with utilities	1	1	1	1	1	1	1	1	1	1					1	1	1				1	1					1	1	1				
if building generates electricity discuss buy-back with the utility company as necessary	1	1	1	1	1	1	1	1	1	1						1					1	1						1					

																			8					
DD																								
Develop transit, pedestrian, and bicycle networks	1	1	1	1	1	1	1	1	1	1	1					1	1			1				
Develop networks of open space, with agricultural greenbelts, wildlife corridors, and stream corridors permanently protected from development	1	1	1	1	1	1	1	1	1	1	1					1	1			1	1			
Develop livable, mixed-use communities, based on the Ahwahnee Principles	1	1	1	1	1	1	1	1	1	1	1					1	1							
Preserve natural site features and restore degraded habitat areas	1	1	1	1	1	1	1	1	1	1	1					1	1	1		1				
Minimize impervious surface areas on the site	1	1	1	1	1	1	1	1	1	1	1			1		1	1		1	1	1			
Manage storm water by working with natural drainage system	1	1	1	1	1	1	1	1	1	1	1			1		1	1	1	1	1	1			
Maximize positive effects of solar orientation and wind patterns, and minimize the urban heat island effect	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1			1		1		
Develop self-sustaining landscape designs based on plants tolerant of soils, climate, and water availability - Maximize use of native plants	1	1	1	1	1	1	1	1	1	1	1					1	1			1				
Maximize efficiency of irrigation systems and consider water reuse strategies	1	1	1	1	1	1	1	1	1	1	1			1		1	1			1	1		1	
Utilize trees and other landscape features to create habitat for wildlife	1	1	1	1	1	1	1	1	1	1	1					1	1			1				
Zone water-using areas within the building and the site	1	1	1	1	1	1	1	1	1	1	1			1		1	1			1			1	
Engage in water-use analysis to develop cost-effective water conservation and reuse strategies	1	1	1	1	1	1	1	1	1	1	1			1		1	1				1		1	
explore opportunities to improve water efficiency of HVAC equipment	1	1	1	1	1	1	1	1	1	1			1	1		1	1					1	1	
explore opportunities to reuse rainwater and/or gray water	1	1	1	1	1	1	1	1	1	1	1			1		1	1						1	
explore opportunities to provide natural wastewater treatment systems for black water on site	1	1	1	1	1	1	1	1	1	1	1			1		1	1						1	
Design the building and site to promote the effective use of daylight and a sense of connection to the natural environment	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1			1				1
protect IAQ by carefully locating building fresh air intakes and exhaust locations	1	1	1	1	1	1	1	1	1	1	1		1			1	1					1		
protect building openings from vehicle pollution and contaminants from landscaped areas	1	1	1	1	1	1	1	1	1	1	1		1			1	1			1		1		

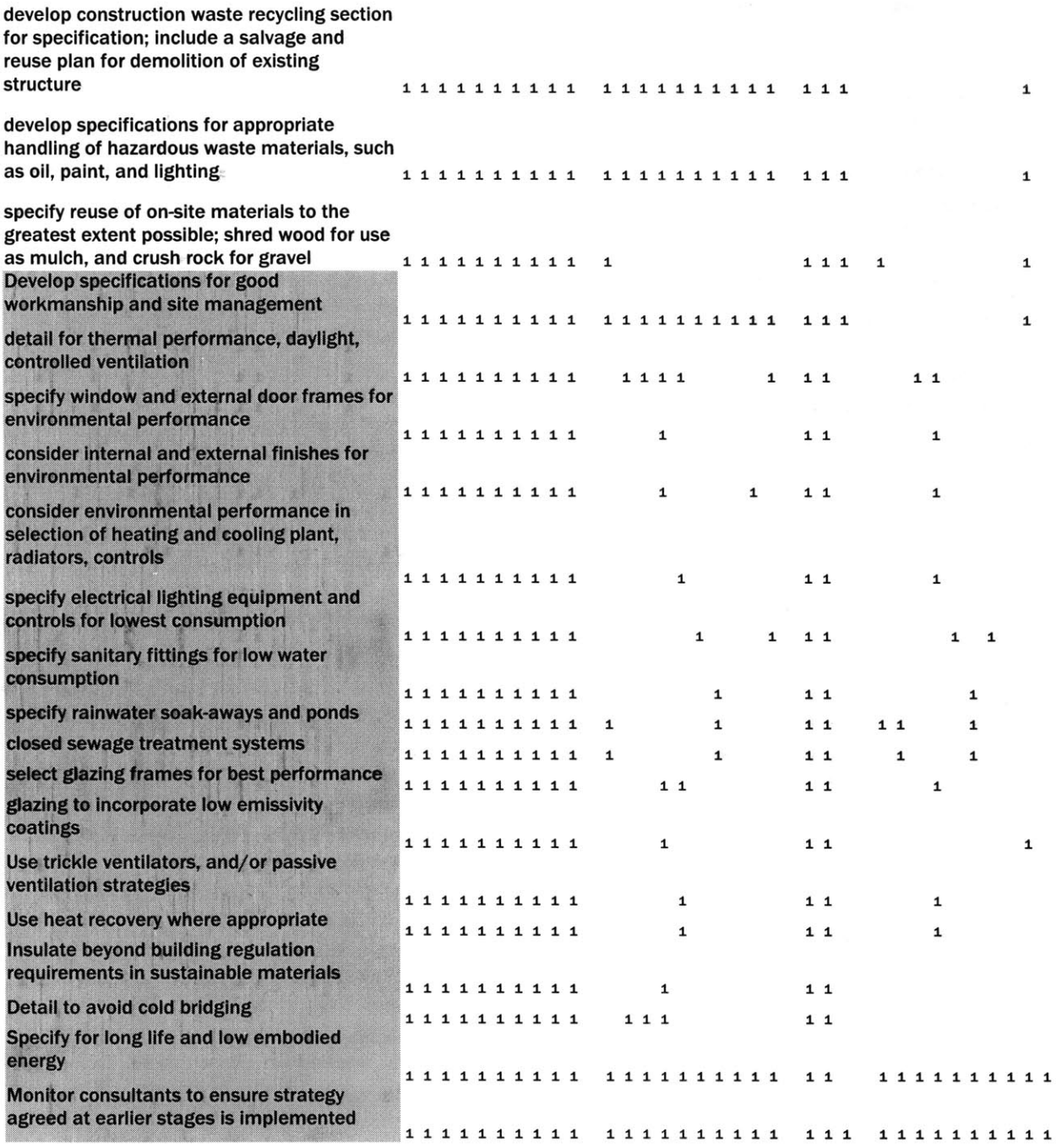
develop design to promote ventilation systems	1	1	1	1	1	1	1	1	1	1					1						1	1					1						
isolate all interior pollutant-generating sources (such as copy machines, chemical storage areas, etc.) to avoid contamination of indoor air quality	1	1	1	1	1	1	1	1	1	1					1				1		1	1											
design for easy access to and maintenance of HVAC equipment: eliminate internal duct liners	1	1	1	1	1	1	1	1	1	1					1						1	1					1						
explore opportunities to enhance flexibility and future adaptability	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
evaluate and select building materials and systems that reduce impacts to the environment and the health of building occupants, over the full life cycle of each	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
explore opportunities to use locally available materials and products and salvaged materials	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
design for disassembly of materials and systems	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
for projects that involve demolition, propose salvage, reuse, and recycling of demolition materials	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1										
integrate requirements for materials collection systems for recycling into the building design	1	1	1	1	1	1	1	1	1	1									1		1	1											
Finalize layout for statutory approvals: implications for daylight/ventilation/passive and active systems	1	1	1	1	1	1	1	1	1	1				1	1					1	1	1				1	1			1			
select materials and construction methods having regard to thermal mass, openings and shading, sourcing materials.	1	1	1	1	1	1	1	1	1	1		1	1		1						1	1				1	1						
confirm earlier decisions on site and building plans: siting and positioning for isolation and shelter; form for over-shadowing; layout and extent of hard and soft landscaping	1	1	1	1	1	1	1	1	1	1	1			1	1						1	1		1			1						
consider disposal of surface water within the site	1	1	1	1	1	1	1	1	1	1	1						1				1	1		1	1								
Consider treatment of polluted water from vehicle hard standings	1	1	1	1	1	1	1	1	1	1	1										1	1		1	1								
Confirm floor to floor heights to maximize daylight and natural ventilation and avoid overheating	1	1	1	1	1	1	1	1	1	1			1			1				1	1	1				1	1			1			
confirm façade proportions, and provision and design of external shading to prevent overheating	1	1	1	1	1	1	1	1	1	1				1	1					1	1	1					1						
consider opening sections in windows for passive ventilation	1	1	1	1	1	1	1	1	1	1				1	1												1						

consider previous decisions on sustainable materials	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1		1	1	1		1	1	1	1	1	1	1	1	1	1
Consider long life and loose fit building structure and the adaptability of the structure	1	1	1	1	1	1	1	1	1	1			1	1									1	1					1							
Long-term adequacy of load-bearing capacity	1	1	1	1	1	1	1	1	1	1			1	1									1	1					1							
Ensure accessibility to ductwork, pipes and wires, with removable covers, demountable trunking.	1	1	1	1	1	1	1	1	1	1						1	1	1					1	1						1	1					
Size conduit drops in walls for easy rewiring	1	1	1	1	1	1	1	1	1	1							1						1	1							1		1			
Develop design of building services systems from sustainable principles	1	1	1	1	1	1	1	1	1	1						1	1	1					1	1						1	1	1				
make calculations of building energy performance	1	1	1	1	1	1	1	1	1	1						1							1	1						1						
													9						6	8					8	2					8		9	5	5	5

CD

identify composting facilities for organic waste to reduce solid waste while producing nutrient-rich soil amendment	1	1	1	1	1	1	1	1	1	1													1	1	1								1			
optimize the energy efficiency of site lighting; consider use of photovoltaics	1	1	1	1	1	1	1	1	1	1		1					1				1		1	1	1								1			
Develop a site lighting design that minimizes light pollution	1	1	1	1	1	1	1	1	1	1		1					1				1		1	1	1								1			
Consider recharge stations for alternative - fuel vehicles and signage for carpooling	1	1	1	1	1	1	1	1	1	1		1					1						1	1	1						1					
select and specify environmentally preferable materials for site development	1	1	1	1	1	1	1	1	1	1		1											1	1	1		1									
explore opportunities to re-use on-site materials	1	1	1	1	1	1	1	1	1	1		1											1	1	1		1	1								
evaluate erosion control requirements and consider opportunities for improvements	1	1	1	1	1	1	1	1	1	1		1											1	1	1		1	1								
develop specifications and design detailing based on integrated pest management	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1			1		1	1			1	1	1	1	1	1			1	
include tree preservation easements in contractor specifications	1	1	1	1	1	1	1	1	1	1		1											1	1	1		1									
use the energy model to refine the design	1	1	1	1	1	1	1	1	1	1						1							1	1						1						
develop architectural detailing to support energy design strategies	1	1	1	1	1	1	1	1	1	1			1	1	1	1	1				1		1	1					1	1	1		1			
clearly document energy performance requirements for equipment, lighting, insulation, and glazing, to guard against inferior substitutions	1	1	1	1	1	1	1	1	1	1					1	1	1				1		1	1	1					1	1		1		1	1
optimize performance of individual components of the MEP system	1	1	1	1	1	1	1	1	1	1						1							1	1						1						

provide a direct digital control energy management and control system	1	1	1	1	1	1	1	1	1	1					1	1					1	1					1	1					
develop clear and comprehensive commissioning specifications for inclusion in the contract documents	1	1	1	1	1	1	1	1	1	1					1						1	1					1					1	
consider use of alternative ultra-low-flow or waterless plumbing fixtures	1	1	1	1	1	1	1	1	1	1							1				1	1	1						1			1	
explore opportunities to improve the water efficiency of cooling towers	1	1	1	1	1	1	1	1	1	1					1		1				1	1					1		1				
eliminate need for landscape irrigation to the greatest extent possible, and maximize water efficiency of required irrigation systems	1	1	1	1	1	1	1	1	1	1	1						1				1	1		1					1				
specify water-efficient plumbing fixtures	1	1	1	1	1	1	1	1	1	1							1				1	1							1			1	
specify water-efficient appliances	1	1	1	1	1	1	1	1	1	1							1				1	1							1			1	
develop glazing and sun control strategies to provide comfortable natural daylight without glare	1	1	1	1	1	1	1	1	1	1					1					1	1	1					1			1			
develop detailing to control air and moisture flows and improve comfort	1	1	1	1	1	1	1	1	1	1		1	1	1	1						1	1			1	1							
provide appropriate acoustical separation between sources of noise inside and outside the building	1	1	1	1	1	1	1	1	1	1								1			1	1									1		
develop detailing to reduce cleaning requirements during occupancy by using walk-off mats at building entries	1	1	1	1	1	1	1	1	1	1									1		1	1											
limit the use of fibrous materials, which have potential for microbial contamination	1	1	1	1	1	1	1	1	1	1									1		1	1										1	1
select materials that are low in emissions of particulates, total VOCs and toxic components	1	1	1	1	1	1	1	1	1	1									1		1	1										1	1
consider engaging in emissions testing of building materials and products to screen out those toxic and/or irritating compounds	1	1	1	1	1	1	1	1	1	1									1		1	1										1	1
develop an IAQ management plan for the construction process. Specify the sequence of finish installation, temporary ventilation, and baseline air quality testing	1	1	1	1	1	1	1	1	1	1					1				1		1	1	1				1						
protect IAQ in occupied areas from construction during renovation or phased construction	1	1	1	1	1	1	1	1	1	1					1						1	1	1				1						
develop resource-efficient design detailing based on material modules	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1
develop design detailing that minimizes impacts on indoor air quality	1	1	1	1	1	1	1	1	1	1				1	1				1		1	1					1					1	1
document detailed environmental performance criteria for the environmental performance of materials in the specifications	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1										1	


develop construction waste recycling section for specification; include a salvage and reuse plan for demolition of existing structure
develop specifications for appropriate handling of hazardous waste materials, such as oil, paint, and lighting
specify reuse of on-site materials to the greatest extent possible; shred wood for use as mulch, and crush rock for gravel
Develop specifications for good workmanship and site management
detail for thermal performance, daylight, controlled ventilation
specify window and external door frames for environmental performance
consider internal and external finishes for environmental performance
consider environmental performance in selection of heating and cooling plant, radiators, controls
specify electrical lighting equipment and controls for lowest consumption
specify sanitary fittings for low water consumption
specify rainwater soak-aways and ponds
closed sewage treatment systems
select glazing frames for best performance
glazing to incorporate low emissivity coatings
Use trickle ventilators, and/or passive ventilation strategies
Use heat recovery where appropriate
Insulate beyond building regulation requirements in sustainable materials
Detail to avoid cold bridging
Specify for long life and low embodied energy
Monitor consultants to ensure strategy agreed at earlier stages is implemented

Specify mechanical services components for good energy performance over long life: gas fired condensing boilers, best available thermostatic radiator valves, weather compensating heating system controls, under floor low pressure hot water central heating, mechanical ventilation systems to include heat recovery components, low energy lift installations, passive infrared light switching and compact fluorescent lighting, dual flushing WC cisterns, photoelectric cell operated urinals and washbasins, energy and resource efficient domestic appliances	1	1	1	1	1	1	1	1	1	1						1	1				1		1	1						1	1					
Minimize hot water pipe lengths from storage to point of use	1	1	1	1	1	1	1	1	1	1								1					1	1								1				
																			8							0		9	7					4		8

BID...

Limit contractor's working space to protect pre-existing natural features and vegetations				1	1							1											1	1	1											
Specify to conserve and re-use topsoil				1	1							1																							1	
Give directions on materials handling and storage to minimize waste						1						1	1	1	1	1	1	1	1	1	1		1	1	1										1	
make green design requirements explicit in all tender packages, especially in specialist packages for design and construct works. These requirements will include directives on the use of as-found material; in construction waste minimization, handling and disposal; and on the use of environmentally friendly cleaning materials						1					1	1	1	1	1	1	1	1	1	1	1		1	1	1										1	
	0	0	0	2	2	2	0	0	0	0		4	2	2	2	2	2	2	2	2	2		3	3	3	0	0	0	0	0	0	0	0	0	3	0

CA/ CONSTRUCTION

consider a plant rescue to transplant trees and other vegetation	1	1	1	1	1	1	1	1	1	1		1											1	1	1		1									
protect on-site soil and vegetation during construction	1	1	1	1	1	1	1	1	1	1		1											1	1	1		1									
phase excavation and construction to limit soil erosion	1	1	1	1	1	1	1	1	1	1		1											1	1	1											
treat land-clearing debris as a resource; find high-value use for large timber, shred remaining wood waste for use as mulch, and stockpile soil and rock for reuse	1	1	1	1	1	1	1	1	1	1		1											1	1	1		1									

confirm compliance with all energy requirements in the contract documents	1	1	1	1	1	1	1	1	1	1				1	1													1	1				1	
encourage the contractor to conserve energy during construction	1	1	1	1	1	1	1	1	1	1											1	1	1											
enforce protection and preservation of water sources during construction	1	1	1	1	1	1	1	1	1	1	1						1				1	1	1		1	1								
encourage the contractor to consider water reuse strategies during construction	1	1	1	1	1	1	1	1	1	1	1						1				1	1	1		1					1				
include IAQ in the agenda of regularly scheduled construction meetings	1	1	1	1	1	1	1	1	1	1					1				1		1	1	1					1					1	1
review submittals, samples, and product literature to determine compliance with IAQ standards	1	1	1	1	1	1	1	1	1	1					1				1		1	1	1					1					1	1
include waste management as an agenda item in the pre-start meeting	1	1	1	1	1	1	1	1	1	1											1	1	1											
enforce special environmental requirements related to use of environmentally preferable materials	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1
encourage vendors to reduce packaging, to use reusable packaging, and to transport materials to the site efficiently	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1
Gathering and storage on site of topsoil for subsequent re-use	1	1	1	1	1	1	1	1	1	1	1										1	1	1		1									
Ensure specified components and materials are provided	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1
Adequate protection of existing landscape, water, vegetation, and other site features	1	1	1	1	1	1	1	1	1	1	1										1	1			1									
Ensure correct handling and storage of materials	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1											
Consider use of any as-found elements such as hardcore or earth	1	1	1	1	1	1	1	1	1	1	1										1	1	1		1									
Storage for recycling of polythene and cardboard packaging	1	1	1	1	1	1	1	1	1	1											1	1	1											
Use of environmentally friendly cleaning agents	1	1	1	1	1	1	1	1	1	1											1	1	1										1	
Correct installation of insulation	1	1	1	1	1	1	1	1	1	1				1							1	1	1											
Correct working materials for health: cutting, spraying	1	1	1	1	1	1	1	1	1	1											1	1	1											
Quality of external facing masonry	1	1	1	1	1	1	1	1	1	1				1							1	1	1											
Weather tightness of opening elements	1	1	1	1	1	1	1	1	1	1				1							1	1	1											
Sealing of openings around pipes penetrating the external envelope	1	1	1	1	1	1	1	1	1	1				1	1		1				1	1	1											
Vapor control membranes	1	1	1	1	1	1	1	1	1	1				1							1	1	1					1						
Low emissivity coatings on glazing	1	1	1	1	1	1	1	1	1	1				1							1	1						1						
Correct disposal of toxic waste	1	1	1	1	1	1	1	1	1	1											1	1	1											
Housekeeping regarding waste materials and recycling of packaging	1	1	1	1	1	1	1	1	1	1											1	1	1											
												4	4		8	4	7	4	6	4				0		4	3	8	4	4	3	3	7	5

OCCU

assist the owner in developing a maintenance program that reduces impact on the environment by utilizing organic fertilizers, integrated biological pest control, and water-conserving irrigation measures	1	1	1	1	1	1	1	1	1	1	1				1				1	1	1			1				
quantify operational waste. Publicize and reward recycling efforts	1	1	1	1	1	1	1	1	1	1									1	1								
offer to provide a comprehensive operations and maintenance manual for the facility	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1
offer to assist with ongoing monitoring	1	1	1	1	1	1	1	1	1	1		1	1	1	1		1	1	1	1		1	1	1	1			1
recommend that the owner establish educational and promotional programs	1	1	1	1	1	1	1	1	1	1									1	1								
assist the owner or management company in developing a maintenance program	1	1	1	1	1	1	1	1	1	1									1	1								
educate users about water conservation	1	1	1	1	1	1	1	1	1	1					1				1	1				1				
offer to assist the owner in developing an indoor air quality manual to guide operations	1	1	1	1	1	1	1	1	1	1			1						1	1		1						
recommend that the IAQ manager remain active in the postoccupancy IAQ program	1	1	1	1	1	1	1	1	1	1			1						1	1		1						
offer to provide a comprehensive operations and maintenance manual with a plan that minimizes indoor air quality hazards from cleaning and maintenance products and minimizes waste from building refurbishment, including lighting waste disposal	1	1	1	1	1	1	1	1	1	1			1					1	1	1		1			1			
Maintaining and renewing floor and wall finishes selected for health and environmental performance	1	1	1	1	1	1	1	1	1	1			1				1		1	1								1
Regular cleaning of windows and luminaires	1	1	1	1	1	1	1	1	1	1			1					1	1	1					1			
Maintaining sanitary components to minimize water	1	1	1	1	1	1	1	1	1	1					1				1	1				1				
Maintaining internal and external planting	1	1	1	1	1	1	1	1	1	1	1								1	1	1							
Use of sustainable, non-toxic, biodegradable cleaning agents.	1	1	1	1	1	1	1	1	1	1									1	1								
Application of paint and thin film coatings in properly ventilated spaces	1	1	1	1	1	1	1	1	1	1							1		1	1								1
Annual inspection of active systems to check continued efficiency of boilers, cooling equipment, radiator valves, infrared switching, heating and cooling controls.	1	1	1	1	1	1	1	1	1	1			1						1	1		1						

Operating systems to prevent overheating in summer: moveable shading, night-time cooling	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1		
Operating ventilation systems: both mechanically assisted and passive: fans, natural ventilation, to optimize balance of ventilation, heating and cooling demand	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1		
Operating the building to maximize heat gain in the heating season: control of night-time ventilation, operating blinds to maximize isolation, closing internal doors to retain captured heat, opening shutters to promote desired ventilation	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1		
Illustrating the mechanical system controls such as programming time clocks, operating weather compensating controls, setting thermostatic radiator valves, seasonal manipulation of flow temperatures in heating system	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1		
Operating electrical installations: correct replacement of light fittings, discussion of switching on lighting and power, lighting sensors, power zoning	1	1	1	1	1	1	1	1	1	1			1	1	1	1		1	1
Operating to maximize the use of daylight and minimize use of artificial lighting	1	1	1	1	1	1	1	1	1	1				1					1
Avoiding peak electricity costs by periodically shutting down large plant	1	1	1	1	1	1	1	1	1	1		1	1		1	1	1	1	
Check for air infiltration as a result of drying and shrinking leading to poor air tightness	1	1	1	1	1	1	1	1	1	1	1				1	1			
Investigate energy consumption through an entire heating and cooling season, by reference utilities invoices or electricity, gas, other. These can be compared with reference figures for an assessment of the overall performance of the building users' comfort, particularly in relation to overheating in the cooling season, where air conditioning is not provided and natural cooling methods are employed; and user satisfaction in relation to daylight availability. Questionnaires can be helpful in this regard	1	1	1	1	1	1	1	1	1	1		1			1	1	1		
Monitor room temperatures, either by simple maximum/minimum thermometers linked to computerized recording system, to establish the effectiveness of heating or cooling installations and help determine whether active installations are over-utilized	1	1	1	1	1	1	1	1	1	1		1			1	1	1		

Water consumption, by monthly and yearly meter readings and a daily consumption in liters per head calculated from the number of building users. Data may be checked with reference to established benchmarks to establish the level of performance

DEM...

4.2 Resources

Tool Name	AUTHOR	TYPE	DESCRIPTION	
Eco-Tech: Architecture of the In-Between	Amerigo Marras (Editor)	B		Amazon.com
Build Smarter with Alternative Materials	Leon A. Frechette	B		Amazon.com
The Green Skyscraper: The Basis for Designing Sustainable Intensive Buildings	Ken Yeang	B		Amazon.com
A Primer on Sustainable Building	Dianne Lopez Barnett, William D. Browning	B		Iris Communications www.oikos.com
Ecological Design :Inventing the Future (video)		B		Iris Communications www.oikos.com
A Guide to Developing Green Building Programs	1999 Technical Report, NAHB Research Center	B		www.nahbrc.org
GreenSpec Binder & Directory, 2nd Edition	Environmental Building News	B		www.buildinggreen.com
The Ecological Design Handbook	Fred Stitt (editor)	B		www.amazon.com
Design with Nature	Ian McHarg	B		www.amazon.com

Green Building Materials: A Guide to Product Selection and Specification	Ross Spiegal, Dru Meadows	B	www.amazon.com
Sun, Wind, Light: Architectural Design Strategies	G.Z. Brown	B	www.amazon.com
The HOK Guidebook to Sustainable Design	Sandra. F. Mendler, Wiliam Odell	B	www.amazon.com
Ecologic Architecture	Richard L. Crowther (editor)	B	www.amazon.com
Sustainable Architecture White Papers		B	www.amazon.com
Design for Human Ecosystems: Landscape, Land Use, and Natural Resources	John Tillman, Joan Woodward	B	www.amazon.com
Handbook of Sustainable Building: An Environmental Preference Method for Selection of Materials for Use in Construction and Refurbishment	David Anink	B	www.amazon.com
The Alternative Building Sourcebook: Traditional, Natural and Sustainable Building Products and Services	Steve K. Chappel (editor)	B	www.amazon.com
The Technology of Ecological Building: Basic Principles and Measures, Examples and Ideas	Klaus Daniels, Elizabeth Schwaiger	B	www.amazon.com
Green Building Handbook: A guide to Building Products and Their Impact on the Environment	Tom Woolley (editor)	B	www.amazon.com
Ecology of Building Materials	Bjorn Berge	B	www.amazon.com
Green Building Resource Guide	John Hermannson	B	www.amazon.com
The green guide to specification. An environmental profiling system for building materials and components	N Howard, D Shiers, M Sinclair	B	BREbookshop.com
Greening Federal Facilities: An Energy, Environmental, and Economic Resource Guide for Federal Facility Managers and Designers, 2nd Edition	Alex Wilson (Editor)	B	US DOE National Technical Info. Service 800 553 6847 #1119094
BREEAM for Office 1998	BRE, UK	B	BREbookshop.com
A Green Vitruvius: Principles and Practice of Sustainable Architectural Design	Eoin O'Cofaigh, Eileen Fitzgerald, 1999, James and James Science Publishers	B	http://www.jxj.com
Sustainable Building Sourcebook: Supplement to the Green Building Program	City of Austin Green Building Program	B	CJ Boggs 512 505 3700
greenclips		N	www.greendesign.net/greenclips
biggreen		L	www.buildinggreen.com
High Performance Building Guidelines		G	www.ci.nyc.ny.us/html/ddc/pdf/greentoc.pdf

Bees 2.0		C		www.bfrl.nist.gov/oae/software/bees/download.html
Building for the Future: Strategies to Reduce Construction and Demolition Waste in Municipal Projects		R		www.informinc.org/buildforfuture.php
Guide to Resource Efficient Building Elements 6th Edition		G		www.crbt.org/
WasteSpec: Model Specifications for Construction Waste Reduction, Reuse, and Recycling		G		www.tjcog.dst.nc.us/cdwaste.htm
IEA Annex 31		R		http://www.uni-weimar.de/SCC/PRO/
Bequest		R		http://www.surveying.salford.ac.uk/bqtoolkit/index2.htm
Guidelines and Principles for Sustainable Community Design. A study of sustainable design and planning strategies in North America from an urban design perspective. Florida A&M University School of Architecture.		G		http://edesign.state.fl.us/fdi/edesign/news/9607/thesis/thesis.htm
The European Commission		WO		http://europa.eu.int/comm/enterprise/construction/suscon/tgs/tg1/efcmfin.htm
Athena Sustainable Materials Institute		WO		http://www.athenasmi.ca/
GBTool		GC		http://www.iisbe.org/
United States Green Building Council		WO		http://www.usgbc.org
Natural Resources Defense Council		WO		http://www.nrdc.org/cities/default.asp
Environmental Defense Scorecard		W		http://www.scorecard.org/chemical-groups/one-list.tcl?short_list_name=pbt
The Sustainable Design Resource Guide		G		http://www.aiacolorado.org/SDRG/home.htm
BRE		WO		http://www.bre.co.uk/centres/index.html
BEES 2.0	United States U.S. National Institute of Standards and Technology	C	Evaluates cost-effective green building products using LCA Compares environmental and economic performance data for generic building materials	http://www.bfrl.nist.gov/oae/software/bees.html Free Download
ATHENA	Canada ATHENA Sustainable Materials Institute	C	Compares building assembly options for low-rise commercial, institutional, light industrial and residential buildings	http://www.athenasmi.ca/ Online animated tutorial Educational Discounts

ENVEST	United Kingdom BRE	C	Identifies elements with most influence on building's environmental impact and shows the effects of selecting different materials based on user input Predicts the environmental impact of various strategies for heating, cooling and operating a building	http://www.bre.co.uk/service.jsp?id=52 web based envest2 due summer 2002
ECOQUANTUM	Netherlands IVAM	C	Quantifies building's environmental impact. Evaluates energy consumption, materials, water consumption, indoor climate and the building's location.	http://www.ivambv.uva.nl/uk/index.htm Free download available
SCALDS - Social Cost of Alternative Land Development Scenarios	Estimates monetary and non-monetary costs associated with urban land development at the metropolitan scale. Uses average cost data as the default values for the calculation of costs	C		http://www.fhwa.dot.gov/scalds/scalds.html
MIT DESIGN ADVISOR	United States Massachusetts Institute of Technology	W	Very easy tool to use, understand and interpret results	http://www.nrel.gov/buildings/energy10/ Demo not available Schools can purchase 2 licenses for $500
Green Building Advisor	United States BuildingGreen	C	User-friendly	http://www.buildinggreen.com Purchase cd-rom for $179
Building Design Advisor 3.0	United States Lawrence Berkeley National Laboratory		Easy to interpret graphical output In development stage - many bugs cumbersome	http://gaia.lbl.gov/bda/ Free download available
Energy Scheming	United States Energy Studies in Buildings Laboratory Department of Architecture University of Oregon	C	Understanding energy fundamentals and familiarity with Macintosh is helpful	http://www.eren.doe.gov/buildings/tools_directory/software/energysc.htm available for purchase from U. of Oregon $49 for students

MOIST	United States Building and fire Research Laboratory National Institute of Standards and Technology	C	Predicts the one-dimensional transfer of heat and moisture Allows user to vary building materials and their relative placement and predicts resulting moisture accumulation within each as a function of time for the selected climate	http://www.bfrl.nist.gov/863/moist.html Free download available
WUFI-ORNL/IBP	United States Oak Ridge National Laboratory and the Fraunhofer Institute in Building Physics (IBP)	C	Advanced hydrothermal model that solves the coupled heat, and moisture transport in building envelope systems such as walls and roofs	http://www.ornl.gov/ORNL/BTC/moisture/ Free download available
LIGHTSCAPE	United States autodesk	C	Advanced lighting and visualization program. Radiosity technology produce accurate photometric simulations of diffuse lighting.	http://usa.autodesk.com/adsk/section/0,,775058-123112,00.html
RADIANCE	United States Lawrence Berkeley National Laboratory	C	Suite of programs for analysis and visualization of lighting in buildings Predicts illumination, visual quality and appearance of innovative design spaces and evaluates new lighting and day lighting technologies	http://radsite.lbl.gov/radiance/ Free Download Available
ADELINE	United States Lawrence Berkeley National Laboratory	C	Provides information about the behavior and performance of indoor lighting systems for both natural and electrical problems Processes geometric, photometric, climatic, optic and human response data to produce numeric and graphic information	http://radsite.lbl.gov/adeline/HOME.html Single cpu license for $200

ODEON	Denmark	C	Simulates the interior acoustics of buildings where, from the geometry and properties of surfaces, acoustics can be calculated, illustrated, and listened to. Ideal for large room acoustics.Based on prediction algorithms image-source method and ray tracing. Import DXF file from CAD. Modest calculation time Visual results. Easy to copy and export results. Used to predict and optimize room acoustics in already planned buildings or improving existing buildings	http://www.dat.dtu.dk/~odeon/ free demo available
CATT-Acoustic v7.2	Sweden	C	Randomized Tail corrected Cone -tracing (RTC-II) combines image-source method, cone tracing, and ray tracing. Requires some understanding of acoustics Imports AutoCad files. Used to predict and optimize room acoustics in design development.	http://www.netg.se/~catt/ Downloadable demo
PHOENICS	England CHAM	C	Predicts quantitatively how fluids flow in and around buildings, humans, engines, lakes, etc... Relatively easy to use Simple Geometries	http://www.cham.co.uk/phoenics/d_polis/d_info/phover.htm Demo not available Annual licenses available
FLUENT	United States	C	Simulation Tool Heat transfer/Phase Change, moving &deforming meshes, multiphase flows, reacting flows, rotating equipment, transient flows	http://www.fluent.com/ Demo CD available
STAR-CD	International CD adapco Group	C	analyzes complex fluid flow, heat transfer, chemical reaction and combustion process	http://www.cd-adapco.com/products/star.htm Demo not available

ENERGY -10	United States	C	Integrates daylighting, passive solar heating, and low-energy cooling strategies with energy-efficient shell design and mechanical equipment Geared toward buildings of 10,000 square feet or less. Base case built based on location, total square footage, and use category program generates alternatives	http://www.nrel.gov/buildings/energy10/ Demo not available Schools can purchase 2 licenses for $500
BLAST	United States	C	Family of programs for predicting heating and cooling energy consumption in buildings and analyzing energy costs. High level of expertise required to develop custom system and plant models.	http://www.bso.uiuc.edu/BLAST/index.html Demo not available Available for purchase from $450 - $1500
ENERGYPLUS	United States	C	Models heating, cooling, lighting, ventilating, and other energy flows. Builds on BLAST and DOE-2 . Time steps of less than an hour, modular systems and plant integrated with heat balance-based zone simulation, multizone air flow, thermal comfort, and photovoltaic systems. High level of computer literacy not required Engineering background helpful for analysis portions Difficult to use without graphical interfaces	http://www.eren.doe.gov/buildings/energy_tools/energyplus/ Free download

DOE2	United States	C	Predicts the energy use and cost for all types of building Uses building layout, constructions, usage, conditioning systems (lighting, HVAC, etc.) and utility rates provided by the user, and weather data, to perform an hourly simulation of the building and to estimate utility bills. Recommend 3 days of formal training in basic and advanced DOE-2 use Demands high level of user knowledge	http://www.doe2.com/ Free Downloads v2.1and2.2 http://gundog.lbl.gov/dirsoft/d2whatis.html different versions from $300- $1200
ECOPROFILE	Norway	C	Top down method for environmentalassessment of existing office buildings. It consists of three mainareas; Outdoor environment, Use of recourses and Indoor environment	http://www.surveying.salford.ac.uk/bqtoolkit/tkpages/ass_meth/methods/amecopros_4.html
ESCALE	France CSTB (Centre Scientifique et Technique du Bâtiment)	C	Assess the environmental performances of a building project at the design stage. The results are expressed according to 11 main criteria (corresponding to outdoor environment at different scales, and to users comfort and health).. The final profile is expressed in easily understandable performance scores.	http://crisp.cstb.fr/view_rdworks.asp?id_rdworks=11

LEED	United States United States Green Building Council	G	Point based system with categories in Site, Energy, Water, Indoor Environment and Materials References existing building codes and standards. Following checklist is simple. Earning a rating is relatively easy. A Platinum rating requires innovation. The current documentation process is cumbersome and time consuming.	http://www.usgbc.org
BREEAM	United Kingdom, Canada, Hong Kong BRE	G	Review and improve environmental performance throughout the life of a building Assesses range of building's environmental impact Awards credits for meeting environmental targets. Simple, understandable, and established. Report prepared by registered accessory	http://products.bre.co.uk/breeam/breeam1.html
GBTOOL	International Green Building Challenge(GBC) International Initiative for a Sustainable Built Environment	G	Hierarchical system of environmental assessment for buildings Framework for scoring and weighting, using data generated in external models to perform detailed studies Attempt to standardize definition of green building internationally. Many options built in so can be overwhelming at first. Is easy to hide things you don't need.	http://www.iisbe.org/ Free download available
ECOEFFECT	Sweden KTH Centre for Built Environment	G	Method to calculate and assess a building's lifetime environmental loads Focuses on Energy use, materials use, indoor environment, outdoor environment and life cycle costs	http://www.bmg.kth.se/Bob/EcoEffect/hemengel.html

CITYgreen	United States Environmental Systems Research Institute	C	Conducts complex statistical analyses of ecosystem services and creates easy-to-understand maps and reports. Calculates $ benefits based on your specific site conditions.	http://www.americanforests.org/productsandpubs/citygreen/ Free download available
SCALDS - Social Cost of Alternative Land Development Scenarios	United States Federal Highway Administration	C	Estimates monetary and non-monetary costs associated with urban land development at the metropolitan scale. Uses average cost data as the default values for the calculation of costs	http://www.fhwa.dot.gov/scalds/scalds.html
COMMUNITY VIZ	United States	C	Create and manipulate a virtual representation of a town and explore different land use scenarios. Suite of tools includes scenario constructor, policy simulator, and sitebuilder	http://www.communityviz.com/ Available for purchase Free demo available
INFRACYCLE FISCAL IMPACT	United States	C	Calculates the capital, maintenance, replacement and operating costs of all municipal infrastructure and the future revenues, comparing costs and revenues to determine if revenues will support costs.	http://www.infracycle.com/products.html
Ecological Footprint Quiz	International	W	Web-based ecological footprint calculator for many countries and languages	http://www.earthday.net/footprint/index.asp
Scorecard	United States	W	Local pollution indicators and comparisons specific to United States	http://www.scorecard.org
Climate Change Calculator		W	interactive software tool designed to raise people's awareness of the greenhouse gases they produce through their daily activities and lifestyle choices. Web based calcualtor	http://www.climcalc.net/eng/Intro_1.html
QUEST	Canada Envision Sustainability Tools Inc.	W	Interactive game that allows you to develop "what if?" scenarios for the future of the region. A Suite of Collaborative	http://www.basinfutures.net/play_gb_quest.cfm

Regional Visioning Tools. Game like interface. The model is easy to use by non-technical audiences; thus it can facilitate understanding among stakeholders about the implications of different policy decision

5.0 Bibliography

Austin Energy's Green Building Program (2000). Sustainable Building Sourcebook. Austin: Austin Energy.

Baldwin, R. & Yates, A. & Howard, N. & Rao, S. (1998). BREEAM 98 for offices. London:. BRE.

Barnett, D.L. & Browning, W.D. (1998) A Primer on Sustainable Building. Rocky Mountain Institute.

Beaumont, C. E. (1996) Smart States, Better Communities. Washington, D.C: National Trust for Historic Preservation.

Benyus, J.M. (1997). Biomimicry. New York: William Morrow and Company.

Berge, B. (2000). Ecology of Building Materials. Massachusetts: Architectural Press

Brand, S. (1994). How Buildings Learn. Penguin books, New York, New York.

Brown, G.Z. & DeKay, M. (2001). Sun, Wind & Light: Architectural Design Strategies. New York: John Wiley & Sons

Building Green. (1999-2001). Green Spec Binder Product Directory. Vermont: Capital City Press.

Calthorpe, P. (1993). The Next American Metropolis. New York: Princeton Architectural Press.

Carson, R. (1962) Silent Spring. New York: Houghton Mifflin Company.

Center for Design at RMIT University. (2001). Background Report LCA Tools, Data and Application in the Building and Construction Industry. Australia: Environment Australia Department of the Environment and Heritage,.

Center for Design at RMIT University (2001) Building LCA Tools Description: Greening the Building Life Cycle: Life Cycle Assessment Tools in Building and Construction, Environment Australia Department of the Environment and Heritage, Australia.

Chappell, S. (1998). The Alternative Building Sourcebook: for Traditional, Natural and Sustainable Building Products & Services. Maine: Fox Maple Press.

CHPS, Inc. (2002). CHPS Best Practice Manual 2002 Volume 1 – Planning.

Cole, R.J. (2001) Lessons learned, future directions and issues for GBC. Building Research & Information, 29(5). 355-373.

Crowther, R.L. (1992). Ecologic Architecture. Boston: Butterworth Architecture.

Daniels, K. (1997). The Technology of Ecological Building: Basic Principles and Examples. Boston: Birkhauser.

Drew, P. (1989). Leaves of Iron- Glenn Murcutt:Pioneer of an Australian Architectural Form. Australia: The Law Book Company Limited.

Dobney, S. (1998). T.R. Hamzah & Yeang: selected works. Victoria: Images Publishing Group Pty Ltd.

Dunham-Jones, E. (2000) Seventy Five Percent - The Next Big Architectural Project, Harvard Design Magazine 12.

Earth Pledge Foundation (2000). Sustainable Architecture White Papers. New York : Earth Pledge Foundation.

Eikelboom, R.T. and Ruwiel, E. and Goumans, J.J.J.M. (2001) The building materials decree: and example of a Dutch regulation based on the potential impact of materials on the environment. Waste Management, 21, 295-302.

Eisenberg, D. & Done, R. & Ishida, L. (2002). Breaking Down the Barriers: Challenges and Solutions to Code Approval of Green Building. Tuscon: Development Center for Appropriate Technology.

Eisenberg, D. and Yost, P. (2001) Sustainability and Building Codes, Environmental Building News, 9,8-14.

Elkadi, H. (2000) Ecological approach for the evaluation of intelligence energy features in a building's skin. Renewable & Sustainable Energy Reviews, 8, 91-103.
Ellis, M.W. & Mathews, E.H. (2001) A new simplified thermal design tool for architects. Building and Environment, 36,1009-1021.
Energy Information Administration, U.S. Department of Energy. (2000). Emissions of Greenhouse Gases in the United States. Author.
Evans, B. (1998). How smart is your building? Architect's Journal;19, 59.
Everett, A. (1994). Mitchell's Material. England: Longman Scientific & Technical.
Frechetee, L.A. (1999). Build Smarter with Alternative Materials. California: Craftsman Book Company.
Gangemi V. & Malanga R. & Ranzo P. (2000). Environmental management of the design process. Managing multidisciplinary design: the role of environmental consultancy. Renewable Energy, 19, 277-284.
Harris D.J. (1999). A quantitative approach to the assessment of the environmental impact of building materials. Building and Environment; 34,751-758.
Hart, S. (1997). Beyond Greening – Strategies for a Sustainable World. Harvard Business Review.
Hawken, P. & Lovins, A. & Lovins, L.H. (1999). Natural Capitalism – Creating the Next industrial Revolution. New York: Little, Brown and Company.
Hawkes, D. (2000). Flow of ideas: Bennett's Associates in Bath. Architecture Today, 113, 60-76.
Hermannsson, J. (1997). Green Building Resource Guide. Connecticut: Tantum Press.
Hess, K. (1997). Environmental Site Assessment. Florida: CRC Press LLC.
Howard, N. & Shiers, D. & Sinclair, M. (1998). The Green Guide to Specification: An Environmental Proifiling System for Building Materials and Components. London: BRE.
Hong, T. & Chou, S.K. & Bong, T.Y. (2000). Building simulation: and overview of developments and information sources. Building and Environment, 35, 347-361.
How Many Planets? A survey of the global environment. (2002, July 6) The Economist. Insert.
Hsin,R. (1996) Guidelines and Principles for Sustainable Community Design. A study of sustainable design and planning strategies in North America from an urban design perspective. Florida A&M University School of Architecture. Retrieved from the World Wide Web May, 2003: http://edesign.state.fl.us/fdi/edesign/news/9607/thesis/thesis.htm
Hui, S.C.M. & Cheung, K.P. (1999) Developing a web-based learning environment for building energy efficiency and solar design in Hong Kong. Solar Energy, 67, 151-159.
International City/ County Management Association (1998). Why Smart Growth: A Primer, Smart Growth Network. Washington DC.
Jensen, M.B. & Persson, B. & Guldager, S. & Reeh, U. & Nilsson, K. (2000). Green structure and sustainability – developing a tool for local planning. Landscape and Urban Planning, 52, 117-133.
Levin, H (2003). Ten Basic Concepts for Architects and Other Building Designers: Best Sustainable Indoor Air Quality Practices in Commercial Buildings. Retrieved May 14, 2003 from the World Wide Web: http://www.buildinggreen.com
Leopold, A. (1949). A Sand County Almanac. London: Oxford University Press.
Lerup, L. (2000). After the City. Cambridge, Massachusetts: MIT Press.
Lyle, J.T. (1999). Design for Human Ecosystems: Landscape, Land Use, and Natural Resources. Washington, D.C: Island Press.
Lowe, S. (2000, May/June) Differentiation: A Key Business Strategy for "Green" Design and Construction Firms. Environmental Design & Construction. 52-56.
Malin, N. (2003). The Going Rate. Architecture, 94, 45-46.
Mandell, J. (2003). The Going Rate. Architecture, 94, 49.

Manning, P. (1995). Environmental Design as Routine. Building and Environment, 30, 181-196.
Matheou, D. (1995). Competitive instinct. Architect's Journal;9,16-17.
McHarg, I.L. (1992). Design with Nature. New York: John Wiley & Sons.
Mendler, S.F. & Odell, W. (2000). The HOK Guidebook to Sustainable Design. New York: John Wiley & Sons.
Metropolis (2002). Teaching Green: Full Survey Report. Found May 21, 2003 on the World Wide Web: http://www.metropolismag.com/html/conferences/icff_2002/teachinggreen_survey_2002.html.
Muradiank, R. (2001). Ecological thresholds: a survey. Ecological Economics, 38, 7-24.
NAHB Research Center (2000). A Guide to Developing Green Builder Programs. Washington, DC: US EPA' Office of Solid Waste and Office of Policy Development.
Nattrass, B. & M. Altomare. (1999) Interface, Inc.: the Next Industrial Revolution, In The Natural Step for Business. (pp. 101-124). Gabriola Island: New Society Publishers.
The Nature Conservancy. (1997). 1997 Species Report Card: The Status of U.S. Plants and Animals. Author.
Neumayer, E. (2001) The human development index and sustainability – a constructive proposal. Ecological Economics, 39,101-114.
Olgyay, V. (1992). Design with Climate – a bioclimatic approach to architectural regionalism. New York: Van Nostrand Reinhold.
Partidário, P.J. and Vergragt, Ph.J. (2000). Shaping sustainable technology development in the coatings chain Defining boundaries, environmental problems and main players. J. Cleaner Prod, 8, 201-214.
Pitts, A.C. (1996). Teaching renewable energy and the sustainable building network. WREC, 1179 - 1183.
Reijnders L.and van Roekel A. (1999). Comprehensiveness and adequacy of tools for the environmental improvement of buildings. J. Cleaner Prod, 7, 221-225.
Riley, J. (2001) Multidisciplinary indicators of impact and change – Key issues for identification and summary. Agriculture, Ecosystems and Environment, 87, 245-259.
Robèrt, K. (1995). Cycle of Nature – Schumacher Lecture. Found May 21, 2003 on the World Wide Web: http://www.geocities.com/combusem/ROBERT.HTM.
Robèrt, K. (2000) Tools and concepts for sustainable development, how do they relate to a general framework for sustainable development, and to each other? J. Cleaner Prod, 8, 243-254.
Roberts, J. (2001) The State of Green Building. http://www.housingzone.com/green/index.asp
Romm, J. J. (1994). Lean and Clean Management. New York: Kodansha America Inc.
Slessor, C. (1997). Eco-Tech Sustainable Architecture and High Technology. New York: Thames and Hudson Ltd.
Soebarto V.I. and Williamson T.J. (2001) Multi-criteria assessment of building performance: theory and implementation. Building and Environment, 36, 681-690.
Spiegel, R. & Meadows D. (1999). Green Building Materials – A Guide to Product Selection and Specification. New York: John Wiley & Sons, Inc.
Spirn, A. W. (1984). The Granite Garden. U.S.: BasicBooks.
Stahel, W.R. (1997). "The Functional Economy: Cultural and Organizational Change. In Richards, D.J. (Ed.), The Industrial Green Game: Implications for Environmental Design and Management. (pp. 91-100) Washington, D.C.: National Academy Press.
Steele, J. (1997). Sustainable Architecture: Principles, Paradigms, and Case Studies. New York: McGraw-Hill.
Stitt, F.A. (1999). Ecological Design Handbook. New York: McGraw-Hill.

Sustainable Building Task Force (2001). Building Better Buildings: A Blueprint for Sustainable State Facilities. Retrieved from the World Wide Web: http://www.ciwmb.ca.gov/GreenBuilding/Blueprint/Blueprint.pdf

Thermie programme of the European Commission DGXVII (1999). A Green Vitruvius. London: James and James.

Todd, J.A. & Crawley, D. & Geissler, S. & Lindsey, G. (2001). Comparative assessment of environmental performance tools and the role of the Green Building Challenge. Building Research and Information, 29 (5), 324-335.

Trust for Public Land (1998). Protecting the Source - Land Conservation and the Future of America's Drinking Water. San Francisco: Author.

Trusty, W.B. & Meil, J.K. & Norris, G.A. Athena: a LCA decision support tool for the building community.

Trusty, W. B. (2000, July) Introducing an Assessment Tool Classification System. Advanced Building Newsletter,25, 18.

Van Der Ryn, S. & Cowan, S. (1996). Ecological Design. Washington, DC: Island Press.

Veleva, V. & Ellenbecker, M. (2001). Indicators of sustainable production: framework and methodology. J. Cleaner Prod., 9, 519-549.

Veleva, V. & Bailey, J. & Jurczyk, N. (2001). Using Sustainable Production Indicators to measure Progress in ISO 14001, EHS System and EPA Achievement Track. Corporate Environmental Strategy, 8 (4), 326-338.

Von Weizsacker, E.U. (1998) Dematerialization – Why and How? In P. Vellinga, F. & Berkhout, & J. Gupta (Eds.), Managing a Material World (pp:45-54). London: Kluwer.

Wackernagel, M. et al. (2002) Tracking the ecological overshoot of the human economy. PNAS, 99 (14), 9266-9271.

William McDonough Architects (1992). The Hanover Principles- Design for Sustainability. USA: William McDonough & Partners.

Wilson, A. (2001). Greening Federal Facilities: An Energy, Environment, and Economic Resource Guide for Federal Facility Managers and Designers. Brattleboro: Building Green.

Wilson, E. O. (1984). Biophilia. Cambridge, MA: Harvard University Press.

Woolley, T. & Kimmins, S. & Harrison, P. & Harrison, R. (1997). Green Building Handbook. Great Britain: E & FN Spon.

The Worldwatch Institute (2002). State of the World 2002. New York: W.W Norton & Company.

The World Commission on Environment and Development (1987) Our Common Future. Oxford: Oxford University Press.

Yagi, K. and Halada, K. (2001) Materials development for a sustainable society. Materials & Design, 22,143-146.

Yates, A. (2001) Quantifying the Business Benefits of Sustainable Buildings. BRE

Yeang, K. (1999). The Green Skyscraper. Munich, London, New York: Prestel Verlag.

Zeiher, L.C. (1996). The Ecology of Architecture. New York: Whitney Library of Design.

Zimmerman, A. (2000) Final Report of the Canadian Team for Green Building Challenge 2000.

U.S. EPA. (1991). Our Built and Natural Environments–Status and Trends of Wetlands in the Coterminous United States. Author.

U.S. EPA. (1998).A Characterization of Building-Related Construction and Demolition Debris in the United States. Author.

USGBC (2002). Building Momentum. National Trends and Prospects for High-performance Green Buildings. Retrieved May 20, 2003 from the WWW: http://www.usgbc.org.

U.S. Green Building Council (1996) Sustainable Building Technical Manual, Public Technology Inc, U.S. Retrieved May 20, 2003 from the WWW: http://www.usgbc.org.

Additional Web Resources

Athena Sustainable Materials Institute http://www.athenasmi.ca/
Australian Life Cycle Inventory Data Project - http://www.cfd.rmit.edu.au/lca/LCAframe3.html
BRE - BREEAM, EcoHomes, Envest, Environmental Benchmarking tool for property portfolios, Sustainable transport, Environmental Management Toolkits, Environmental impacts of construction materials and products, http://www.bre.co.uk/centres/index.html
Bequest http://www.surveying.salford.ac.uk/bqtoolkit/index2.htm
Info on – BEES 2.0, BREEAM, BRE Environmental Profiles, CIE, EcoPoint, Ecoprofile, EcoProP, Eco-Quantum, ENVEST, EIA, GBC, The Green Guide, PIMWAQ, SIA,
BRE - BREEAM, EcoHomes, Envest, Environmental Benchmarking tool for property portfolios, Sustainable transport, Environmental Management Toolkits, Environmental impacts of construction materials and products, http://www.bre.co.uk/centres/index.html
Building Connecticut Leadership in Green Buildings and Clean Energy – A Report to Connecticut Innovations – April, 2001.
Building Energy Software Tools Directory - http://www.eren.doe.gov/buildings/tools_directory/database/page.cfm?Cat=EnergySim&Status=Yes&Menu=1&Sel=1&Desc=Energy+Simulation
Centre of Environmental Technology, Limited. HK-BEAM (New Offices) An environmental assessment for new office designs version 1/96. Hong Kong.
Denver AIA Committee on the Environment *The Sustainable Design Resource Guide* http://www.aiacolorado.org/SDRG/home.htm
Development Center for Appropriate Technology - http://www.dcat.net/home.html
EcoEffect - http://www.bmg.kth.se/Bob/EcoEffect/hemengel.html
EcoInvent - http://www.ecoinvent.ch/
Ecoprofile – Feb 2000
EnergyStar - http://www.energystar.gov/
EnergyPlus - http://www.eren.doe.gov/buildings/energy_tools/energyplus/cfm/regForm.cfm
ENVEST – DEMO
Environmental Defense (2001) http://www.scorecard.org/chemical-groups/one-list.tcl?short_list_name=gg Regulatory Controls Environmental Hazards Lists.
The European Commission (1999) Task Group 1 Final Report: Environmentally Friendly Construction Materials, http://europa.eu.int/comm/enterprise/construction/suscon/tgs/tg1/efcmfin.htm
GaBi Software - http://www.gabi-software.com/
Green Building Challenge 2000. GBC Assessment Manual: Volume 1
Green Building Challenge 2000. *GBTool* http://www.iisbe.org/
IEA Annex 31 - http://www.uni-weimar.de/SCC/PRO/
KCL-ECO - http://www.kcl.fi/eco/indexn.html
LCAid http://www.projectweb.gov.com.au/dataweb/lcaid/
LISA - http://www.lisa.au.com/
Millennium Project (1996) *Environmental Security Study,* http://www.geocities.com/CapitolHill/Senate/4787/millennium/env-sec1.html.
National Lighting Product Information Program - http://lrc102.lightingresearch.org/nlpip/
National Resources Defense Council - http://www.nrdc.org/cities/default.asp
Natural Resources Defense Council http://www.nrdc.org/cities/default.asp
PEMS 4 LCA Software - http://www.edie.net/Library/Features/IEG9736B.html
Residential Energy Services Network - http://www.natresnet.org/
Simulation Research Group at Lawrence Berkeley National Laboratory http://gundog.lbl.gov/
Sinum – REGIS, EcoPro, Umberto - http://www.sinum.com/htdocs/e_software_download_form.shtml

Sustainable Products Purchasers Coalition - http://www.sppcoalition.org/
The Sustainable Design Resource Guide – Denver AIA Committee on the Environment - http://www.aiacolorado.org/SDRG/home.htm
TEAM – LCI Tool - http://www.ecobalance.com/software/team/
United States Green Building Council (2001) *LEED Green Building Rating System,* http://www.usgbc.org.
U.S. D.O.E. Center of Excellence for Sustainable Development. http://www.sustainable.doe.gov/greendev/princpl.shtml
University of Texas, Houston, health Science Center http://www.uth.tmc.edu/ut_general/admin_fin/ss/FPD/