TOWARD SUSTAINABLE BUILDING - GREEN BUILDING DESIGN AND INTEGRATION IN THE BUILT ENVIRONMENT

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A thesis submitted in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE IN ARCHITECTURE

WASHINGTON STATE UNIVERSITY
School of Architecture & Construction Management

May 2007

To the Faculty of Washington State University

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ACKNOWLEDGMENT

I wish to acknowledge my Chair Hal Rumsey by providing support and working with me to accomplish this thesis, and the effort on the part of my committee members, James Holt and Ray Ladd.

I also want to thank my associate Barry Markle in providing critique and help in reviewing the thesis and providing constructive feedback. I want to thank Marilyn Kolehmain for providing editing services and helpful ideas on the format of the paper.

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Abstract

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Sustainability is a multifaceted concept that encompasses the human, social, economic and environmental aspects of our society. It has led to the emergence of a larger concept of sustainable development. By definition it can be described as meeting the needs of the present without compromising the ability of future generations in meeting their own needs.

One of the major business enterprises where sustainable development is occurring is in the construction industry, which has caused the emergence of sustainable building, or green building. This represents a great opportunity to design buildings that are resource efficient use less energy, curb wasteful practices from construction, and provide healthier environments for occupants.

Green building development involves an integrated approach where building professionals collaborate closely on achieving sustainable goals and better efficiency in building projects. This new industry is expanding through the support of various organizations like the U.S. Green Building Council, as well as public institutions and city governments that are requiring certain green standards in new construction of public facilities. Research shows that green building is a growing industry locally and across

Washington State. Initial first costs can be higher, but the payback can be quick through energy savings and productivity gains. The result is significant savings for building owners over the life of the building. The emergence of sustainable building, or green building, has brought about an awareness of what the building industry can do to curb high energy use, minimize waste, and create environments that are healthy and productive.

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Chapter 1

INTRODUCTION

Our developing world has caused many to be concerned over sustaining our resources, environment, and way of life. We face an escalating population growth and the concern over having enough resources for development to meet our needs in the present and that of future generations. Our society has created a business production paradigm that needs more planning to preserve our natural capital, and to minimize waste in the process of development. Although growth is important, it must be done efficiently and with the mindset that many of our resources are finite.

The consumption of material and energy in the United States has increased at an alarming rate over the past two decades, especially in the built environment. Oil, gas and coal have taken millions of years to form, but our consumption is depleting supply. There may be hidden reserves, but extracting them may not be practical because the harder they are to extract the more energy is needed to access those reserves. The resources that are used must come from carefully managed practices that minimize waste and foster efficient production.

Modern capitalism has pursued development and growth without enough forward thinking to sustain our natural environment, until recently. As described by author Herman Daly, "We are consuming the earth's natural resources beyond its sustainable capacity of renewal." [1] Fifty to a hundred years ago we did not feel it was urgent to

[1] Herman Daly, *Beyond Growth* (Boston, 1996), 61

understand the relationship between business and a healthy environment. But, in the new millenium, we know that it is imperative to alter wasteful development and work toward a more restorative process that not only helps to preserve our valuable resources, but improves the quality of life for all of humanity. In the United States alone, billions of dollars have been spent cleaning up local environments that have been the result of uncontrolled development. Most people would probably agree that innovation and technology are essential in our world to progress and make new discoveries that benefit mankind. Yet at the same time, there has been an effort by governments and business enterprise over the years to move toward a more balanced way of growth that is sustainable. This is the cause of sustainable development. It leaves much room for interpretation, but it has been generally embraced by many international organizations, governments and business enterprises.

Sustainable development can be described as meeting the needs of the present without deterring the ability of future generations to meet their own needs. It encompasses a broad focus that include; the effect development has on our biosphere, energy conservation, and the impacts of the built environment in our world, sustainable communities, and economic and social sustainability. A major focus of sustainable development is in the built environment or the buildings in which we live and work. Since buildings in the United States consume 36% of the country's energy supply and 30% of raw material use, continued action is necessary to address the impact that building construction has on depletion of these resources, our energy supply, and the

environment as a whole. Also, since we spend as much as 90% of our time in buildings, we are significantly affected by our interior living and working environments. [2]

It will be the goal of this thesis to address the issues of sustainable development in our built environment. This thesis will attempt to answer questions on whether the new emphasis on sustainability in our building industry is helping to improve our environment both externally and internally, is cost effective, affects our health positively, and is a growing factor in our economy. This thesis will also address the emerging market both in our local economy and across Washington State.

[2] Herman Daly, *Beyond Growth* (Boston, 1996), 62.

Chapter 2

SUSTAINABLE BUSINESS

"Then I say the earth belongs to each generation during its course, fully and in its own right, no generation can contract debts greater than may be paid during the course of its own existence." Thomas Jefferson

Great strides were made during the industrial revolution that saw the world expand in its production output of material to fuel massive industrial enterprises like railroads, airplanes, automobiles, machinery and material for the production of products and for building construction. It was a time when resources were plentiful and innovation and growth were the essential mantras for global societies and the United States. Non-renewable resources like oil, coal, and natural gas were abundant and there wasn't concern for conservation of energy and the effect that mass production, had on green house gas emissions and our environment.

Today we are seeing an effort in the business community to curb the tide of excessive use of resources toward a pattern of development that is more sustainable. There is still a long way to go to ensure that consumption of resources doesn't continue to deplete an irreplaceable supply. A sustainable society must be based on using renewable

resources at rates that do not exceed the rate of renewal, and using non-renewable resources at rates that do not exceed our capacity to substitute for them.[3]

Over the last four decades the U.S. has consumed more fossil fuels than it has produced in the form of coal, natural gas, and crude oil. In 1970 we produced 59 quadrillion BTU's of energy and consumed 64 quadrillion BTU's. In 2005 production has gone down to 55 quadrillion BTU's and consumption has gone up to 86 Quadrillion BTU's. At the same time imports of crude oil have gone up. In 1970 the U.S. imported 7 quadrillion BTU's of energy which has increased to 28 quadrillion BTU's in 2005. Nuclear electric power generation has also been increasing since 1970; it has gone from 0.24 quadrillion BTU's to 8. Also, production of renewal energy sources such as, hydroelectric, geothermal, solar and wind for electrical generation has had modest increases.

Since 1970 the U.S. production of alternative energy has gone from 4 quadrillion BTU's to 6 quadrillion BTU's. Consumption of energy in these sectors has been equal to production.[4] All this represents vast amounts of energy consumption needed for transportation, industrial uses, and residential and commercial building development, to name a few. It also fuels the endless need and demand in the U.S. economy for more of everything. The question is how much is enough? If we proceed as usual we may be caught in a repetitive spiral of demand and consumption. The alternative is to take a broader look at a road map that provides a more sustainable way of business development in our society.

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[3] We Are Interested In The Sustainability Of Humans. Sustainability. http://www.jadski.com/kerala/a1sustainability.htm.

[4] Annual Energy Review-Energy Overview. Energy Information Administration. 2006. http://www.eia.doe.gov/emeu/aer/overview.html.

Today's businesses in the U.S. are driven by the idea of limitless growth and the need for short tem results. A business is understandably established to generate profits, but it would be prudent for owners to want to make a positive contribution to society and help minimize any negative effect on the environment. This balancing of economic interests to social and environmental concerns is sustainability.[5] With constant pressure to expand and increase quarterly earnings, too many companies consume natural resources as if there were a limitless supply. . Not enough thought is given to more efficient methods of manufacturing materials, or to implement more ecologically minded processes. At the same time, wastes from production, many hazardous, are being disposed of in whatever means are available and cheapest. Much of our natural resources end up in landfills and incinerators faster than the earth is able to replace those resources.

The essential makeup of our business structure is unsustainable until recently. The good news is that since businesses are the driving forces behind development; they have the power to change directions. As put by author Paul Hawken, "To create an enduring society, we will need a system of commerce and production where each and every act is inherently sustainable and restorative."[6] There has been a trend recently in the U.S. of businesses taking a more responsible outlook into business practices in a world that is being pushed to the limit because of the expanding population and finite resources. Sustainable development in its definition suggests that it applies to the whole world and everyone and everything in it, now and in the future. The aim is for the continuation of this development based on needs and limits. Needs comprise the conditions for maintaining an acceptable life standard for all people, and limits restrict the capacity for

[5] Creating a Sustainable Business. Price Waterhouse Coopers. June 2006. http://www.pwc.com/extweb/challenges.nsf/docid.
[6] Paul Hawken, *Ecology of Commerce* (New York, 1993). 4.

the environment to fulfill the needs of the present and the future.[7] Business needs to continue in this direction, as put by author Jeffery Hollender, "to move beyond the notion of individual sustainable businesses and toward the idea of sustainable business, a new totality in which all companies adopt a doctrine of social and environmental responsibility."[8]

One of the paramount concerns of development is to reduce the negative impacts that development of all types has on the environment through more efficient business practices of acquiring materials, manufacturing and building. We have seen the results of expansive industrial and commercial development. Our atmosphere is filled with carbon dioxide and we have seen the fourteen warmest years on record in the last twenty two. Nearly 20 percent of the world's forest cover has been lost since 1700. Estimated extinction rates are at least 100 times higher than in pre-modern times. Synthetic organic chemical production has increased 3000 percent since 1940, and the bodies of every single man, woman and child now carry dozens of toxins.[9]

A by-product of growth in energy consumption has been in the petrochemical industry which produces 95 percent of all the chemicals in use today. These contain numerous derivatives, many of which are harmful to our health. Most petrochemical products, for example plastics, appear to be safe. But the production process and the waste produced can be harmful. And, many of these products are used in building construction, which may have additional adverse effects on the environment. Many of thee petrochemical products are combined with chlorine which produces a wide variety

[7] What Is Sustainable Development. Sustainable Architecture And Building Design. http://www.arch.hku.hk/research/BEER/sustain.htm.
[8] Jeffery Hollender, *Sustainable Planet* (Boston Massachusetts, 2002). 64.
[9] Ibid.,.65.

of toxic emissions and polluting wastes that can't be recycled. When disposed of, they emit further atmospheric, liquid and solid pollutants. Air pollution causes extensive environmental degradation.[10] (Figure 2.1).

Causes of Air Pollution	
Carbon Dioxide	Increasing in the atmosphere it builds up and acts like a blanket over the earth, trapping its heat causing global warming and affecting weather patterns. Everyone contributes, residents of large areas generate about 10 tons of carbon dioxide a year.
Carbon Monoxide	Is emitted by the incomplete combustion of fossil fuels for home heating, lighting, manufacturing and transportation. It is colorless and odorless because it inhibits the health functioning of human and animal organs and blood cells. Estimates are that the average human adds 3 tons of carbon monoxide a year to the atmosphere from energy used for transportation, heating and lighting.
Sulfur Dioxide	It is given off from many industrial processes and becomes sulfuric acid when it comes in contact with atmospheric moisture. Like nitrous oxide, if produces acid rain, which damages soil, waterways, lakes and forests
Nitrous Oxide	Reacts with volatile organic compounds (VOCs) found in many home decorating products. It generates a damaging form of ozone at low levels and causes respiratory irritations. When volatile organic solvents (chemicals such as methyl, chloroform, halons and methyl bromides) come in contact with the sun, they produce chlorine, which destroys the ozone layer more rapidly than the earth naturally generates

(Figure 2.1 Causes of air pollution)

[10] Alan Berman, *Your Naturally Healthy House* (Singapore, 2001),15-16.

Waste and pollution can be seen as inefficiencies that decrease profits and damage the environment. Companies may increase their profit margins if they can develop new technologies that make their processes more efficient and minimize waste. For example, these technologies may be producing more efficient machinery and equipment for manufacturing, or production management systems that can increase efficiency and increase profits. Wastes may be a huge by-product of production. If they can't be eliminated, companies should attempt to develop processes where waste can be reused or converted to new products, instead of simple disposal. For example, much of the waste in the built environment can be transformed into new building products.

Consider LaFarge North America Corp. in Minnesota. They are using fly ash to replace a portion of the Portland cement in the production of concrete. Fly ash is recovered from coal- fired power plants; it results in lower cement content that reduces the impact on atmospheric carbon dioxide. Environ Biocomposites makes a bio-based decorative surface material made from soybean flour and newsprint. It looks like granite and works like a hardwood. They also make Wheatboard made from wheat-straw; it has a smooth surface and can be used for table surfaces, cabinetry and other architectural applications. Manomin Resawn Timbers make plank flooring re-milled from antiques of old growth lumber reclaimed from factories, warehouses and old bridges across the county.[11] These are just a few examples of how business is helping to make new products and minimize waste. Working toward a more sustainable business model, companies can become more efficient and ultimately more productive.

[11] Recycled Products Directory. Minnesota Office of Environmental Assistance. http://www.moea.state.mn.us/.

A sustainable business practice also involves the human dimension. An advanced company genuinely shows kindness and favor toward its people; together they create its profits. Leaders should recognize that happy people may be motivated people, the kind that can create innovation and change, and ultimately success. Employees should be seen as equal partners and valued for their contributions and respected as human beings. Companies that are concerned with the health and well being of its employees foster a supportive environment where employees can excel and be more productive.

Sustainable development therefore involves human, economic, environmental and social dimensions. The human element is maintaining human capital, or the private good of the individual. It constitutes the health, education, skills, knowledge, access to services for people, and quality of life. Social sustainable development can mean enhancing the physical, mental and social well-being of the population[12] Social sustainability can also be in the form of people friendly urban design, and development that meets the basic needs of food, shelter, education, health care and work. The economic focus is in sustaining the capital that makes up our social structure and creating new markets and opportunities for business. Environmental sustainability is in maintaining our natural resources, and reducing the harmful impacts that building development and materials have on our external environment.

One major business enterprise that represents significant economic activity in the U.S. is the construction industry. There has been a change in the industry toward sustainable building, or green building. The building industry represents a vast opportunity to utilize innovative product designs as mentioned earlier, and new

[12] "The "Soft Infrastructure" of a Healthy Community." Trevor Hancock. http://newcity.ca/Pages/social_Sustainability.html.

technologies that will conserve energy, and curb the vast amounts of waste generated by construction. There have been continual advances in the industry that incorporate holistic approaches to planning and management of projects, and to developing new products for building. Green buildings are a way to help address the issue of depleting natural resources and energy conservation.

Chapter 3

GREEN BUIILDING

The Office of Federal Environmental Executive describes green building as the practice of increasing the efficiency with which buildings and their sites use energy, water and material, and reducing building impacts on human health and the environment through better siting, design, construction, operation , maintenance and removal.[13] Green building has gained in momentum over the past decade, but it is not new. Some of its early beginnings date back to the nineteenth century. According to David Gissen, curator of architecture and design at the National Building Museum in Washington D.C., structures like London's Crystal Palace and Milan's Galleria Vittorio Emanuele II, used passive systems such as roof ventilators, and underground air cooling chambers to moderate indoor temperatures.[14] In the early twentieth century some skyscrapers in New York used deep-set windows to shade the sun. Later, the Rockefeller Center (1932) utilized both operable windows and sky gardens.

From the 1930's new building technologies transformed the urban landscape. Large enclosed glass and steel structures were built which required the use of massive HVAC systems that consumed vast amounts of energy. The availability in the U.S. of cheap fossil fuels and the postwar economic boom accelerated the development of these structures. It wasn't until the 1970's that a group of forward thinking architects, environmentalists and ecologists questioned the wisdom of building in this manner.

[13] Building Design and Construction's White Paper on Sustainability: A Report on the Green Building Movement. U.S. Green Building Council. 2006. http://www.usgbc.org/Docs/Resources.
[14] Ibid., 4.

Their efforts were given notice by the celebration of the first Earth Day in April 1970. But, it wasn't until the OPEC oil embargo in 1973 that the "environmental movement" caught the attention of the public on a large scale. The skyrocketing gas prices and the long lines at the gas stations caused Americans to wonder about the U.S. relying so heavily on foreign fossils fuels for transportation and building.

At the time, the American Institute of Architects (AIA) responded with an energy task force and later the AIA Committee on Energy. One group looked toward passive solutions like reflective roofing materials and strategic environmental siting of buildings, while the other group concentrated on more technological solutions like the use of triple glazed windows. Even though the energy crisis began to recede, the early efforts of conservation for buildings began to take hold. In England a grass roof, daylighted atrium and mirrored windows were used in a commercial building. California commissioned eight energy-sensitive state office buildings which employed photovoltaics, under floor cooling systems and area climate controlled mechanisms.

In 1977 the Department of Energy was created to address energy use and conservation. At the international level proponents were experimenting with prefabricated energy efficient wall systems, water reclamation systems and modular construction units that reduced construction waste. In 1987 the United Nations World Commission on Environment and Development met under Norwegian Prime Minister Gro Harlem Brundtland to form the Brundtland Commission; they created a vision called "Our Common Future." [15] They first articulated that the goal was to foster sustainable

[15] Building Design and Construction's White Paper on Sustainability: A Report on the Green Building Movement. U.S. Green Building Council. 2006. http://:www.usgbc.org/Docs/resources/BDC WhitepaperR2.pdf.

development in our world that would meet the needs of the present without compromising the ability of future generations to meet their own needs.

During following years, the AIA Energy Committee was transformed into a broader scope that brought about the development of a guide to building products based on life cycle analysis. This led to published documents that encouraged numerous building products manufacturers to make their products more ecologically sensitive. The president of the AIA, Susan Maxman, participated in the international "Earth Summit" which developed a blueprint for achieving global sustainability. Sustainability was the theme for the World Congress of Architects which brought the issue of sustainability to the forefront with the signing of the Declaration of Interdependence for a Sustainable Future. This convention was considered the turning point in the green building movement.

Building construction and operation have an enormous direct and indirect impact on the environment. Buildings use vast amounts of energy and raw materials and produce waste and harmful emissions to the environment. Typical buildings in earlier decades were big users of chlorofluorocarbons (CFC) that degrade the ozone layer, and fossil fuels that emit greenhouse gases. As economies and population expand, designers and builders face an increasing challenge to meet the demands of new and renovated buildings that are secure and healthy while minimizing harmful effects of the environment. Every industry has the potential to contribute in the efforts of creating more efficient business and production operations that can result in energy savings, especially in building construction.

In the United States buildings account for:

- 36% of total energy use /65% of electricity consumption
- 30% of greenhouse gas emissions
- 30% of raw material use
- 30% of waste output and 136 million tons annually
- 12% of potable water consumption

Different breakthroughs in building systems, design and products are available to architects, builders and owners who want to build green to maximize economic performance and balance environmental issues.[16] For example, this can be in the form of heating, ventilation and air conditioning strategies, passive solar design, efficient lighting, water conservation and cleaner building materials, to name a few.

To remain competitive and to continue to grow with the changing aspects of this new type of development and obtain potential new profits, building industry professionals are addressing the environmental and social consequences of their industry. They are assessing the impact of past business practices that did not consider how development affected the environment and are looking at how to make changes for the future. This enables them to look at new design options and systems that can be used to maximize energy efficiency.

As homeowners and developers become more environmentally savvy and demand more green options in their buildings, a new generation of architects and builders will emerge that is intent on creating more efficient and healthy buildings. These new buildings have only a fraction of the impact on the environment that conventional

[16] Why Build Green. U.S. Green Building Council. 2006. http://www.usgbc.org/DisplayPage.aspx?

building practices have. Smart architects think rationally about issues as sustainability, durability, longevity, using appropriate materials and the efficient use of space. This is not just locally or nationally, but there is an increasing recognition internationally in working with sustainable building.

Chapter 4

SUSTAINABLE DESIGN

Building development in both the residential and commercial sectors represents an enormous opportunity to utilize sustainable principles for conservation of resources, to promote the use of more efficient and healthy products, and to improve the living and working environment for people. The entire life cycle of buildings from design, construction, operation and reuse, has diverse impacts on our environment. This can come in the form of creating greenhouse gases during the extraction and processing of raw material, displacing habitat, and generating waste that overloads existing landfills. To achieve a greater level of environmental sustainability, it is imperative to provide the education necessary to architecture students on environmental issues. One survey conducted at the University of Michigan indicated that there was a shortage of teaching materials on environmental education in architecture, and that architecture educators lack adequate educational resources.[17]

The goal of environmental education in architecture is to increase sustainability in the building sector. Students may be sympathetic to the environmental cause, but they may not be active advocates. The strategy is to stimulate student interests early in the educational process that will foster a greater understanding of how buildings can be designed with an awareness of the environment, and can achieve maximum efficiency.

[17] Jin-Kim, Jong. "Introduction to Sustainable Architecture." National Pollution Prevention Center For Higher Education University of Michigan. 1998: 1-6. http://www.umich.edu/-nppcpub/resources/compendia/Archpdfs/ArchHintintro.pdf.

Further educational efforts will give students the skills and knowledge to find sustainable design solutions.

Architecture is one of the most noticeable and relevant forms of economic activity. Our growth and development as a country will bring about a demand for more factories, office buildings and residential buildings. For some households, a growth in income and family size will foster a need for larger houses with more furnishings, appliances and interior thermal comfort. This expansion and growth brings about new challenges for industry professionals to design and build buildings that are resource efficient, and have good indoor environmental quality.

Because of the vast amount of resources used in construction, it is important to build efficiently because buildings represent roughly 40 percent of the materials entering the global economy each year for residential and commercial construction. Over three billion tons of raw materials are turned into foundations, walls, pipes and panels. The majority of this is essential dirt, rocks, stone, clay for bricks, and gravel and sand for concrete.[18]

The growth of green building has caused architects to seek recycled materials, devise low energy heating ventilation and air conditioning systems, look at indoor air quality issues and renewable energy systems, such as solar and wind. The AIA can also be a major player in directing a new wave of designers in choosing products that are truly green or sustainable by promoting product guides that have chemical analysis of common products and that list less toxic alternatives.

[18] Mark Wasserman, "Designing Sustainable Green Buildings" (New York Institute of Technology, 1995), 4

Sustainable design and construction considers the entire life cycle of buildings from environmental and functional use, to operation and future values. In the building and housing market the demand for quality is growing in importance. It is imperative that polices that contribute to sustainable building practices be implemented. Government will be able to stimulate sustainable building by encouraging these developments through local and national incentive programs which will be discussed later in this report.

Sustainability does not mean a loss of quality of life, but requires a change in a mind-set. Sustainable design uses an alternate approach to traditional design, taking these concepts into account and recognizing the impacts of every design choice on the natural resources of the local, regional and global environments. A model of new design principles necessary for sustainability is exemplified by the "Bill of Rights for the Planet," developed by William McDonough Architects for Expo 2000 held in Hanover, Germany which includes the following:

1. "Accept the responsibility for the consequences of design decisions on human well-being and natural systems."
2. "Eliminate the concept of waste. Evaluate and optimize the full life-cycle of products and processes to approach the state of natural systems in which there is no waste."

These principles were adopted by the World Congress of the International Union of Architects (UIA) in June 1993 at the American Institute of Architects (AIA) Expo 93 in Chicago. This led to a declaration that places environmental and social sustainability at the core of professional responsibility. It also involves educating the building industry,

clients, and the general public about the importance of sustainable design.[19] These activities are an example of how the concept of sustainable design is being supported on a global and inter-professional scale.

There is a trend in the building industry toward adopting new standards of sustainability in construction projects both in the residential and commercial sectors. Governmental bodies and private developers are beginning to more readily accept the principles of green building and seek new designs for their buildings. There are many good business reasons to adopt green building practices in projects which include a potential fast return on higher first costs because of increased operating efficiency, electric, gas and water conservation, and improved indoor environmental quality.

USGBC – LEED

One of the leading proponents to advance this movement is the U. S. Green Building Council (USGBC). Over the last decade the USGBC has emerged as one of the most successful nonprofit membership organizations. It was established to develop a rating system for new construction that would inspire the efficient use of materials, systems, and the conservation of energy resources. Founding President David Gottfried and Chair Rick Fedrizzi, along with experts in the building community, architects, engineers, interior designers, manufacturers, real estate managers and others, created the first sustainable rating system for buildings. The result was the Leadership in Energy and Environmental Design (LEED). It was designed to accelerate the development and implementation of green building practices.

[19] Guiding Principles of Sustainable Design, U.S. Department of the Interior Introduction. http://www.nps.gov/dsc/dsgncnstr/gpsd/.

The primary focus of the LEED rating system is for commercial buildings, but there has also been a recent addition of LEED for homes in the residential sector. The main format for sustainable building is organized into five different categories to maximize the efficiency of a building system relating to siting, water conservation, energy, materials, and indoor environmental quality.[20] (Figure 4.1) There is also a special category for innovation and design. All LEED standards address three types of requirements:

1. Prerequisites – required elements before a project can be considered for LEED certification.
2. Core credits – specific actions a project may take in the five main areas.
3. Innovation credits – "Extra Credit" given for exemplary performance beyond the core requirements or new actions that show significant environmental benefits.

[20] Building Design and Construction White Papere on Sustainability: A Report on the Green Building Movement. U.S. Green Building Council. 2006. http://www.usgbc..org/Docs/Resources/BDC whitepaperR2.pdf.

The LEED-NC 2.1 checklist

Category/possible points	Summary
Sustainable sites 14	Requires the design of a sediment and erosion plan. Site must not be on prime farmland; on land lower that 5 ft. above a 100 year flood plane; on a protected habitat; within 100ft. of wetlands; on public parklands. Offers points for channeling development to urban areas, locating between rail or bus lines, providing bicycle storage and showers for 5% of occupants.
Water efficiency 5	Reduce water consumption for irrigation by 50%; use only captured rain or gray water for irrigation, or do not install landscape irrigation systems. Reduce use of city water for sewage by 50% or treat 100% of waste water on site to tertiary standards.
Energy and atmosphere 17	Must use best practice commissioning procedures. Must design to comply ASHRAE/IESNA 90.1-1999 or more stringent local code. Zero use of CFC-based refrigerants in HVAC systems. Points for reducing design energy costs, supplying 5%, 10% or 20% of total energy use via on-site renewable systems, installing HVAC and fire suppression systems that contain no HCFC's or halons, providing 50% of electricity from renewable sources over a two year contract.
Materials and resources 13	Points for providing an area for recycling waste material, diverting 50%-70% of construction demolition and land clearing waste from landfill, using 5% or 10% of salvaged or reused material, using 5% or 10% of total values of materials from post-consumer recycled content, using 20% or 50% of building materials that are manufactured within 500 miles, using 50% of wood based material from Forest Stewardship Council certified forests.
Indoor Environmental quality 15	Must meet minimum requirements of ASHRAE 62-1999. Must prohibit smoking in the building or provide ventilated smoking rooms. Points for installing a permanent CO2 monitoring system, designing ventilation systems that result in air change effectiveness, using wood and agrifiber products containing no added urea formaldehyde resins, designing to minimize pollutant cross contamination of occupied areas.
Innovation and Design process 5	Points for exceptional performance above the requirements set by LEED or for innovative performance in green building categories not addressed by LEED, having a LEED accredited professional as a principal participant.

(Figure 4.1 LEED rating system)

Each category contains a specific number of credits. Each credit contains one or more possible points that can be applied to achieve different certification levels with a maximum of 69 points. (Figure 4.2)

LEED Certification Levels

Rating	Earned Points
Certified	26-32
Silver	33-38
Gold	39-51
Platinum	52-69

Source: USGBC

(Figure 4.2 LEED certification levels)

LEED has been successful because it takes a complex problem, sustainable design and development, and creates an experience for professionals that engages them in their competitive nature. It also establishes a means of comparison in the real estate market. LEED projects can give a property a seal of approval where owners can state, in theory, that their properties are environmentally superior to a majority of contemporary properties in the market.

According to a recent study, LEED has caused a great deal of activity in the real estate community. Owners of LEED-rated buildings can state that their properties are, at last in theory, environmentally superior to at least 75% of contemporary buildings in the market.[21] Participation in LEED does encourage design teams to consider a wide range of environmental issues. In the hands of skilled and competent professionals, LEED-rated buildings should turn out to be more environmentally beneficial than conventionally designed buildings. [22] Building teams that take on a more integrated approach from the

[21] Building Design and Construction Whitepaper on Sustainability: A Report on the Green Building Movement. U.S. Green Building Council. 2006. http://www.usgbc.org/Docs/Resources/BDCWhitepaperR2.pdf.
[22] Ibid.,10.

beginning of a project, rather than adding LEED features later in the project, can and do reach a more fully integrated project.

The USGBC and the LEED rating system are a major catalyst in inspiring developers, building professionals and architects to move toward a new direction in the construction industry. To remain competitive in the future, more and more firms will become actively involved in LEED and sustainable design as a matter of survival, especially in the public and educational sectors of building construction. As sustainable building increases, more firms will likely join partnerships with like-minded individuals in other disciplines where the practice of sustainable design will become more routine.

Ultimately going green is not a viable alternative if it is not an economical advantage over conventional construction methods. In the building industry, decisions on building design are based primarily on first cost. The extra features incorporated in green building design can add to the cost of a project, but when you weigh out the energy savings over the life cycle of the building, the extra costs create a substantial savings over the long term, as will be discussed later in this report. This does not include the associated effects on worker health and productivity and the increase in value to green properties. All these factors may add to the economic benefits of green building.

An example of a sustainable approach to building can be seen in the Traugott Terrace. It is a commercial and multifamily development in Seattle Washington. The facility is owned and managed by the Archdiocesan Housing Authority. It provides 50 units of clean and sober housing for individuals with very low incomes and broadens the multi-service commercial facility on the first floor that offers programs to stop substance

abuse. It was the first green building project in Seattle which included many innovative green features, and one of the first LEED certified projects in the country.

It was an infill project that resulted in efficient use of space. Light colored, energy star-rated roof coatings were specified to reduce the urban heat island effect of absorbing and releasing heat energy to the surroundings. Water conservation involved low flow fixtures and more efficient front-load washing machines for a water use projection at 39% below typical. Yearly energy savings as compared to similar baseline buildings are projected at 27% or $18,389 per year (at 2002 rates). One main strategy included a well-insulated envelope. Others involved air sealing all windows and door openings, installing low –e windows, heat recovery ventilators for ventilation to all common spaces, using fluorescent lighting throughout with occupancy and photocell daylight sensors, and reducing hot water heating needs due to reduced water consumption.

Many materials used in the Traugott Terrace development contain 46% recycled content, 59% of materials were produced within 500 miles of the project site, and 78% of all wood products are Forest Stewardship Council certified sustainable harvested. This is an example of developing a more sustainable approach to affordable housing. The materials research conducted led to the development of a series of publicly available green material fact sheets for education on green building.[23]

[23] "Traugott Terrace, Green Building Case Study," *Environmental Works Community Design Center* (September 10 2004):1-5.

Chapter 5

BUILDING DEVELOPMENT

Building design and development has gone through many stages from earlier times to the present. The ability to make choices that will advance sustainable building development depends on having enough information to make sound decisions. We find some of the principles of building design and use of products from earlier times are being adopted in today's buildings, especially in the residential sector. Aspects of this new design is the materials used in construction and home furnishings which are in the process of change in today's building industry. This is more closely related to concerns over how products are produced and what their effects are on indoor air quality.

There has been progress over the years in producing less toxic products, but many are still made with harmful materials, such as toxic substances in adhesives, finishes, and chemicals used in glues and dyes, which will be discussed later in this report. The result is an adverse effect on occupant health because of off-gassing, and a negative effect on our environment if toxic waste is not managed properly. However, the sustainable building movement has led to an increasing number of new products available for the green designer.

As mentioned earlier, we spend as much as 90% of our time indoors, and our indoor environment affects our psychological and physical well being. Many architects and industry professionals are working to change traditional construction practices. They are adopting more sustainable approaches to design which involves more recycled content

products, products with low volatile organic compounds (VOCs) such as adhesives and paints, and the use of natural heating and ventilation systems to name a few.

Many of our economic principles of progress and growth are driven by continual consumption which generates increasing volumes of waste. For example, factories powered by fossil fuels produce, on average, 10 pounds of waste for each pound of useful product that they manufacture. We replace today's products with tomorrow's, and most consumer products become garbage after about six weeks. [24]

In pre-industrial building construction, there were fewer problems associated with harmful ingredients used in building products, and people had fewer concerns for their health and environmental well-being in their homes and their places of work. Now at the beginning of the twenty-first century, we have discovered that there are lessons to be learned from our ancestors.

Traditional Home

It is possible to develop an approach to home design that is based on the way that people have built and decorated homes from earlier times. In pre industrial times, homebuilding involved different processes to develop materials and products used in the home. Natural elements, as with wood products and natural finishes, did not contain the toxicity seen in modern construction. Materials were obtained locally and used with care and more in tune with the physical surroundings, such as natural wood finishes, stone, brick and tile. Safe but effective methods were used to naturally heat and cool a building. For example, in desert areas thick walls were made from local desert mud to keep temperatures stable by absorbing the sun's heat during the day and releasing it at night

[24] Alan Berman, *Your Naturally Healthy Home* (London, 2001). 6

when temperatures cooled. In forest areas, roofs of solid logs covered with grass acted as efficient insulators.

Traditional cultures had a tendency to conserve natural resources by using the simplest materials and forms; design did not have to be complex to be attractive and appealing. Many natural-quality building products, such as flagstone, terra cotta tiles and wood paneled walls, are derived in part from their connection to the local landscape and available local skills that provided products. By contrast many mass-produced homes of today have lost their sense of coherence and relationship to their surroundings. They are a mixture of design concepts made possible by wide availability of materials and a plethora of styles from all over the world.

Modern Home

The development of more modern homes in the mid twentieth century gave way to large, mass-produced housing developments and a slew of new products and materials used in home construction since the Second World War. Inexpensive, mass-built housing exploited the new materials and processes offered by the petrochemical industry, of which plastics are the best known example. At the time it wasn't understood that some of the new products released chemicals in the air over time, by the process called off-gassing. Another factor was the desire since the 1970's to conserve energy, with two consequences. First, energy consumption was reduced by increasing insulation in the building, often with such material as urea formaldehyde foam used for wall insulation. Second, this was coupled with the sealing of the home to prevent heat loss. This new building-design principle allowed less heat loss during the winter and heat gain during

the summer, thus reducing the demand on the HVAC systems and overall energy consumption. But, the concern was that the building no longer had enough natural infiltration for air exchange that is necessary for healthy living; which created a "sick building syndrome." People were getting sick from the toxins commonly used in building products that were getting trapped inside the home, along with other household pollutants which will be discussed in more detail later in this report. One solution was to introduce more outside air changes into the building, but this offset the efficiency gained from initially reducing heat loss and heat gain because of the tighter shell.

Fireplaces and the drafty nooks were sealed off trapping human-generated germs, toxins, moisture and the vast number of chemicals that are vaporized and off-gassed. This so-called advanced building technology created home environments with previously unknown dangers.

Outside of indoor air quality problems, the modern house had other issues to overcome. The mass production and standardization of many homes today leaves little room for variation because there aren't the differences from one house to another in some housing developments. We have produced homes that in many cases have become modular packages that can be constructed anywhere. This approach is convenient for an economy set for mass production because it allows for the centralized production of materials and housing, as in the case of mobile homes.

The modern approach to housing is appealing to many, but the admiration for traditional styles by some of today's home buyers suggests that there is a need to connect with those styles associated with our ancestors. This is seen in the expanded development of straw bale and earthen type homes, and the use of more natural materials like cork and

bamboo. The interest in traditional styles may not always carry with it the ability to acquire materials and skills locally, as before, because using local materials is not always practical in today's global environment. But, the idea of using appropriate materials is very valid. Going beyond the aspect of selecting materials for their appropriateness, it would be prudent to think about the environmental impact of our choices. However appropriate the material; we must be sure that its production, transport, use and ultimate disposal are easy on the environment.

Efficient building will require that homes be constructed with materials that are sustainable, that are made with as little energy as possible, that are safe and that have the capability of being reused or recycled for future use.

Green Home

Home building has seen dramatic changes over the years, but some patterns from the past are making headway for current building techniques. Many materials we think of as modern actually have been used for thousands of years. Brick, concrete, glass, metal and wood are all building materials that, for the most part, have remained largely unchanged from previous times. As mentioned earlier, clay, mud and straw bales are being used in some of today's building construction as an alternative to wood stick and metal framed buildings. The sustainable approach to building involves creating an awareness that material selection affects the environmental picture. It also proposes that the nature of alternative green building design results in considerable energy savings and a healthier place to live and work because of improved indoor air quality. Another attribute includes

selective recycling of construction waste materials to divert them from landfills where some of the waste can be converted into new products.

Sustainable home design involves other elements in seeing that a project is developed properly. The client must insist on it and have the knowledge necessary to know what to look for in green products. Green building projects are not in the majority of architectural commissions at the present time. The green projects being done require a progressive alliance of clients and designers. Finding a green-educated architect may be difficult. A client may want to seek out an architect who wants to pursue green design, and information is readily available to interested architects.

Energy and environmental costs are most easily reduced by decisions made early in the design process, through siting and orientation. Using intelligent design, architects can reduce the energy cost and negative impacts of buildings by 50 to 90 percent below conventional buildings.[25]

Getting a builder to understand the needs of green building can be difficult and frustrating. Builders are used to building houses for the fewest dollars per square foot. It may be difficult for the conventional builder to accept the notion that spending more money for green options is worth while. It is up to the client and the architect to explain to the builder the reasons why they want to use such items in the design and the willingness to spend the extra money.

Selecting the site is a primary consideration for a sustainable building. There are many considerations for site selection but one of the main ones is for energy conservation. This is in the form of utilizing one of our most valuable resources, the sun.

[25] Mark Wasserman, "Designing Sustainable Green Buildings" (New York Institute of Technology,1995),16

Positioning the building with the right southern exposure is very important. South facing houses ensure lower energy consumption during the winter because the solar gain offsets the heating load requirements for the building. With the proper shading and incorporating designs for natural ventilation, the solar gain can be minimized during the summer, resulting in less demand for central air conditioning.

According to a recent study by McGraw Hill, green building should ramp up 30% in 2007 over the 2006 levels with more than two-thirds of residential builders constructing green homes. Already 90% of builders report participating in some green-building activities. The majority of builders (56%) report that buyers are willing to pay more for a green home, but there are obstacles. Many builders (82%) cite higher first costs as an obstacle to building greener homes.[26] Other obstacles include lack of education about concepts, codes and regulation. However, consumer demand is considered the most important reason why the residential market is getting so much greener. The primary factors that buyers value are energy efficiency and indoor air quality.

Commercial and Multifamily Buildings

On a larger scale, multifamily dwellings and commercial buildings represent a great potential to incorporate sustainable design for more resource-efficient buildings. The introduction of the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) program has inspired governments, private developers and industry professionals to design high performance buildings. Creative designs include natural day lighting that reduces the lighting electrical load, natural ventilation

[26] Green Building and the Bottom Line. Building Design+Construction. November 2006. http://www.bdcnetwork.com/contents/pdfs/whitepaper 06.pdf.

strategies that offset the cooling load, and innovative heating systems that can save energy.

Other sustainable strategies may include green roof systems that absorb water and reduce run off, and water reclamation systems where rain water is captured and reused for irrigation or diverted to bio swales to alleviate the impact on the city's storm drainage system. Also, gray-water recovery systems can be designed where the water can be filtered and reused in the building to flush toilets. Innovative new and recycled content products are more readily available for a multitude of uses that may include paneling, flooring and counter tops. Also, adhesives and finishes are being made with low VOCs that have no off-gassing, helping to reduce the sick building syndrome. This is a continual challenge for building professionals to incorporate new products into building design because indoor air quality is a major concern in the workplace and in the home which will be discussed later in this report.

The process of green-building design in multifamily projects involves bringing together building professionals and the community to design a complex where specific sustainable goals can be met. This may not only mean such things as energy-efficien,t passive-solar design and super-insulated building shells, but also special features like multipurpose community centers, community gardens, adequate bicycle storage to promote alternate forms of transportation, and locating buildings in close proximity to local transportation.

An example of a sustainable multifamily project is the Sustainable Housing Innovation Partnership (SHIP) developed by the Spokane Neighborhood Action Programs (SNAP), a non-profit, community-action agency. It involved a partnership

between SNAP and other interested parties in 2000. The goal was to design, fund and build a low-income housing project based on sustainable design and construction. The result was Riverwalk Point I (RWP 1), a 5-building, 52-unit affordable housing project serving families at risk. SNAP used many principles of sustainability. Part of the development process was the design charette (a gathering of various groups to collaborate on the overall project design). The owner, designer, engineer, business professionals, the public, and potential tenants all partook in design and landscape charettes that resulted in an innovative, practical, and energy-efficient project design. (Figure 5.1)

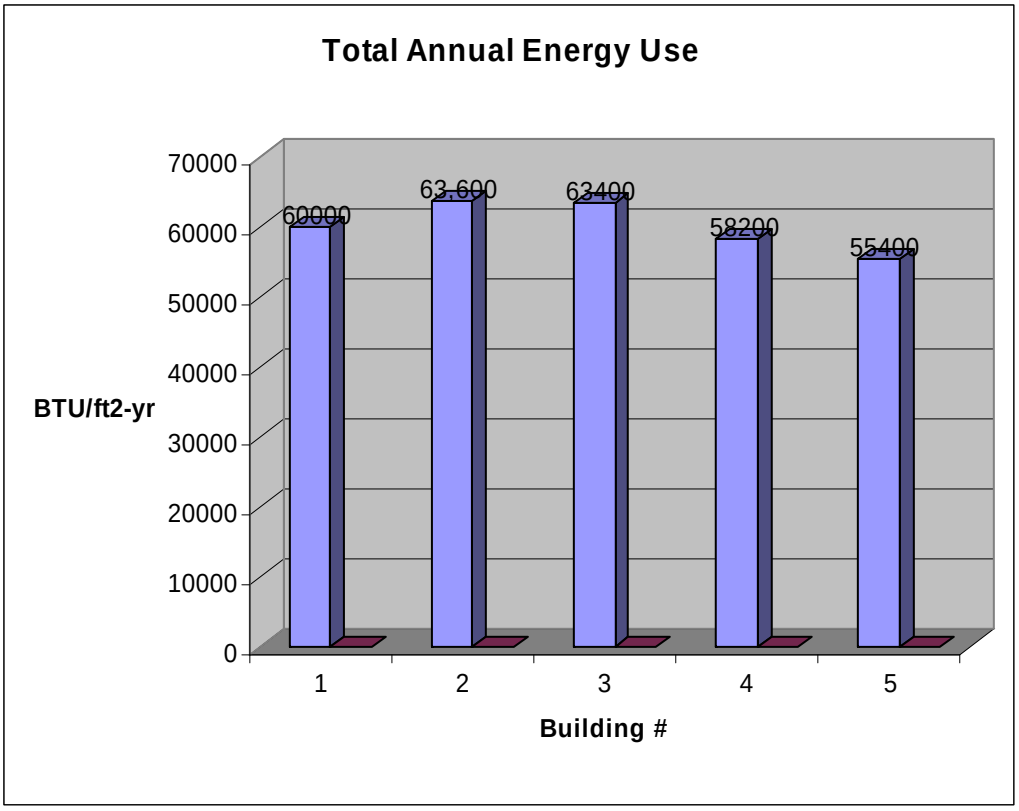
The design included recycled content products such as drywall, engineered wood, asphalt and the use of flyash (a by-product of coal burning) in concrete. Other features in the project included passive solar design and building framing using finger-jointed studs (made from short lengths of lumber formerly scrapped or burned for fuel). One building was constructed using structural insulated panels (SIPs) which can create a tighter building shell. Healthier products were also incorporated such as low-toxic cabinets, sub-floors and underlayment, water-based adhesives, mastics and grouts, and interior and exterior paints and finishes.

During the design process, different building technologies were considered. Three of the five buildings (buildings 1, 4, and 5) were constructed with identical floor plans but with different building shells and mechanical systems. Ninety-one percent efficient gas furnaces were used in all buildings except Building 5 which had ground source heat pumps. Building 4 used SIPs instead of traditional stick frame construction.


(Figure 5.1 Riverwalk Point Building 2)

Monitoring was done to assess the performance of the buildings and compare the benefits of alternative technologies. Data was collected from May 2003 through May 2004. Over the peak months of the heating season, November through March, Building 5 with the heat pumps, used considerably less energy annually than the buildings with the forced-air, gas-heating systems. Overall Building 4 with the SIPs had lower annual energy use than buildings 1, 2 and 3, but did not outpace Building 5. (Figure 5.2). The graph represents the total annual energy use per square foot for each building. Comparisons of total energy use for the monitoring period are altered by occupancy

levels, and because Building 5 with the ground-source heat pump system, was the only building with air conditioning.[27]



(Figure 5.2 Total annual energy use Riverwalk Point buildings 1 - 5)

This is a comparative analysis of different sustainable design approaches that can be used in today's green residential construction. All the main measures, including high-efficiency low u-value windows and doors; well insulated walls, floors and ceilings; high-efficiency space and water heating equipment; air sealing of duct systems and building envelopes; selection of materials to minimize off-gassing pollutants; and integrated whole-house systems were above the Washington State Building Code. SNAP

[27] David Hales, " Performance Analysis of the RWP1/SHIP project." May 2004.

and other non-profit agencies have been moving toward a more sustainable approach when developing affordable multifamily housing projects.

Chapter 6

MATERIALS AND INDOOR ENVIRONMENTAL QUALITY

As mentioned before, how buildings affect the health of their occupants is a major construction industry issue and principal concern of the green-building movement. It is brought about by various building design features that affect the overall makeup of the building's interior. The sick building syndrome (SBS) and building related illness (BRI) are major classes of problems associated with building health. SBS describes various symptoms experienced by occupants where no specific cause can be identified. This can be seen where the affected employee's symptoms disappear almost immediately when they leave the building. In contrast, BRI refers to a specific diagnosable illness that can be associated directly with a defined indoor air-quality problem. Indoor environmental quality (IEQ) refers to the physical quality of the indoor environment as opposed to its aesthetic quality. A major part of IEQ is indoor air quality (IAQ), but IEQ goes beyond just air quality to include other elements:

- Indoor air quality (levels of pollutants such as building product emissions, external pollutants, dust and pollen)
- Humidity (moisture in the air)
- Air movement (fresh air and drafts)
- Acoustics (noise transmission between rooms)

- Light intensity and quality (from windows, skylights, and artificial lighting)[28]

Indoor air quality is mainly concerned with the respiratory effects of chemicals, biological agents, and particulates, and will be discussed more in detail in later in this chapter. Both the residential and commercial sectors have similar design and building challenges in dealing with indoor air quality. There are many elements in the buildings that can be detrimental to the health of occupants. Since indoor environmental quality is a major concern in today's building designs, the sustainable-building movement is working to alleviate the problem. As discussed earlier, the need for quality less toxic products and furnishings for homes and commercial buildings is imperative because super insulating and sealing a building can lock in toxins and inhibit fresh-air infiltration.

Air quality is one of the most important aspects of the indoor environment. The Environmental Protection Agency (EPA) considers indoor air quality one of the greatest single factors contributing to ill health; a fact not widely acknowledged until recently. Studies of indoor environments show that many modern materials and chemicals contribute to a large list of environmentally induced illnesses. It is also estimated that the dozens of potentially harmful chemicals in our homes can be up to 1600 times more potent when combined.[29] A smell often will alert us to the problem, but even if we don't smell them it doesn't mean that pollutants aren't present. The following is a summary of various pollutants found in the home. (Figure 6.1)

[28] Sustainable Buildings Industry Council, *Green Building Guidelines:Meeting The Demand For Low-Energy,Resource-Efficient Homes* (2004), 97.
[29] Ibid.,18.

Major Indoor Air Pollutants in Homes[30]

Pollutant	Source	Health Effects	Steps To Reduce
Radon	**Earth, rock, well water, building materials**	**Lung cancer**	**Test, seal cracks in floors, ventilate crawlspaces**
Tobacco Smoke	**Cigarette, pipe cigar smoke**	**Eye, nose, throat irritation, headaches**	**Stop smoking**
Biologicals	**Wet walls, ceilings, carpets, poorly maintained humidifiers**	**Eye, nose, throat irritation, dizziness, fever, asthma**	**Vent kitchens and bathrooms, cloths dryers, clean and dry wet carpets**
Carbon Monoxide	**Un-vented kerosene and gas heaters, leaking chimneys, furnaces**	**Fatigue, impaired vision, headaches, dizziness, nausea**	**Adjust gas appliances, ventilate over stoves**
Nitrogen Dioxide	**Kerosene heaters, un-vented gas stoves, tobacco smoke**	**Eye, nose, throat irritation, impaired lung function**	**Adjust gas appliances, ventilate over stoves**
Respirable Particles	**Fireplaces, woodstoves, kerosene heaters, tobacco smoke**	**Eye, nose, throat irritation, bronchitis, lung cancer**	**Vent furnaces, choose proper sized wood stoves**
Organic Gases	**Paints, stains and strippers**	**Headaches, dames to liver and kidneys**	**Use manufacturers recommendation, ventilate area**
Formaldehyde	**Plywood, paneling, particleboard, furniture and pressboard**	**Eye, nose, throat irritation, wheezing, coughing, fatigue, skin rash**	**Use exterior grade pressed wood products, increase ventilation**

(Figure 6.1 Indoor air pollutants in the home)

[30] Environmental Protection Agency, "The Inside Story A Guide to Indoor Air Quality." Sept. 1988.

Many household cleaning products are also the sources of toxic elements inside the home and can be substituted with healthier products. These can include baking soda or borax instead of bleach cleaners and white vinegar instead of ammonia-based cleaners. There are many steps that can be taken to minimize exposure to harmful pollutants. Reducing exposure by source control and using less or non-toxic materials and products are the most effective ways to create a healthier indoor environment. This is a constant challenge because of the elements listed above that are found in the home. Poor indoor environmental quality can be summarized in different categories. (Figure 6.2)

Poor Indoor Environmental Quality

Off-gassing

From materials this is the slow release into the atmosphere of chemicals that vaporize. These materials include VOCs and other petrochemicals such as benzene, naptha, formaldehyde and organophosphates contained in PVC's.

Particulate and biological contaminants

All atmospheres contain very fine invisible airborne particles including household dust, animal hair and dander, microorganisms, pollen and mold spores as well as smoke and asbestos.

Combustion gases

Can be emitted by old, faulty, or badly maintained heating systems, furnaces and water heaters that only partially burn their fuels

Electromagnetic fields

Electricity and electrical installations surround us everywhere. They include low frequency electrical fields emitted from cables and equipment and magnetic fields from all appliances and equipment which are considered the most dangerous.

(Figure 6.2 Poor indoor environmental quality)[31]

[31] Alan Berman, *Your naturally Healthy House*(London,2001).21-22

Despite these problems, there are strategies for making homes healthier places to live. Over the last two decades many building products and household products have been designed that use less toxic components, especially with the movement in green building where new materials and products are cleaner, resulting in not using formaldehyde in wood products, and low VOCs in stains and paints, to name a few. With the reduction in toxic elements and the introduction of controlled ventilation in the buildings, there is a possibility of an energy-savings benefit from a tighter building shell resulting in minimal heat loss in the winter and less demand on cooling in the summer.

Most of the structures that are the cause of the sick building syndrome are modern office buildings, many of which have been constructed over the past two decades and are tightly sealed and have few or no operable windows. The most common complaints are flu-like symptoms or respiratory-tract infections. Also, occupants note other ailments such as stress like headaches, coughs, and the inability to concentrate. Commercial buildings carry some significant sources of pollutants from building materials and systems.[32] (Figure 6.3)

[32] Mark Wasserman, "Designing Sustainable Green Buildings," (New York Institute of Technology, 1995), 44.

Indoor Air Pollutants in Office Buildings

Pollutants	Source	Health Effects
Benzene	Synthetic fiber, plastics, cleaning solutions	Central nervous system damage, respiratory irritant
Formaldehyde	Urea formaldehyde insulation, spackling compounds, insulation products, ceiling and floor tiles	Eye and skin irritation nausea, headaches, fatigue
Micro-organisms	Humidifying and air conditioning systems, evaporative condensers, cooling towers	Respiratory infection, allergic responses
Paint fumes	Freshly painted surfaces	Respiratory system and eye irritation, kidney and bone marrow damage
Pesticides	Spraying of plants and premises	Liver damage, cancer, neurological damage, skin and eye irritation
Sterilant gases	System to sterilize humidifying and air conditioning systems	Respiratory system and eye irritation, genetic damage and cancer
Tobacco smoke	Cigarettes, pipes, cigars	Respiratory system and eye irritation, may lead to lung cancer
Trinitroflourenone	Photocopiers	Liver cancer, lung dysfunction central nervous system
Vinyl chloride	Plastic products, pipes, light fixtures, upholsterers, carpets	Carcinogen, suspended mutation, dermatitis, bronchitis

(Figure 6.3 Indoor air pollutants in office buildings)

The high-performance building movement has been very successful in integrating indoor environmental quality issues into the overall criteria for green building. It is expected that a high-performance green building will have excellent IEQ. In particular, the USGBC's LEED guideline standards address IEQ and provide points for incorporating at least some of the major IEQ components. This includes effective IAQ and individual control of temperature and humidity.

Optimizing material selection is a key component of a green building. Environmentally friendly building materials are a growing field with more product choices every year. The following segment will address key issues to material selection. All materials have emissions, and they may all contribute to a deterioration of air quality. Material selection is a complex process involving many variables, and there is not necessarily one best method that can be used across the board for selection. As mentioned earlier, green material selection typically involves an assessment of a product's life-cycle and environmental impacts. This process tracks the raw materials used, its production process, the transportation, intended use, and disposal, reuse or recycling options. Through this process a number of attributes have been identified for various construction materials.[33]

- Renewability- These are materials that are rapidly renewable, derived from biological sources such as trees and agricultural products. Examples include natural linoleum, cork, bamboo, straw-based board products like cabinet-grade particle board, and some engineered wood products.

[33] Sustainable Building Industry Council, *Green Building Guideline Meeting The Demand For Low-Energy Resource-Efficient Homes* (2004), 109.

- Recycled content – refers to post-consumer material generated by commercial, industrial, institutional and households that can no longer be used. Post-industrial materials are recovered industrial process wastes that cannot be reused in the same process, such as slag-from metal smelting.
- Reuseability /recyclability – describes how easily a product can be reused or recycled once it has reached the end of its service life. Products that are easily disassembled or separated from other materials should be considered.
- Durability – this describes what the expected maintenance and service life of a product may be.
- Embodied energy – is the energy required to extract, process, package, transport, install, and recycle or dispose of materials that make up the building. Up to 70% of the total energy invested in a building's construction is embodied in the material. Because of the energy required to transport, it is preferred to select products that don't require long distance shipping.
- Environmental impact – refers to the effect a material has on the indoor environmental quality and its effect on the outdoor environment and atmosphere. For example, select products that do not contain Hydro fluorocarbons (HFCs), halons, etc.

Specifying green products, therefore, becomes a specialized process that requires a lot of thought and consideration because of the various options in the marketplace. Although many companies may market products as green, they don't always live up to

the expectations. From windows to interior finishes, the designer is faced with selections for energy efficiency and maximizing indoor environmental quality.

Windows

Windows are a vital aspect of building design, giving occupants a connection with the outside. Careful choice and placement of windows is one of the most direct ways the indoor climate can be controlled. In new homes, windows typically account for 15% to 30% of total heat loss and for overheating in the summer.[34] Operable windows provide one of the simplest and cheapest forms of passive ventilation, reducing the need for cooling systems. Many advances have been made in the design of windows from the initial single pane windows to super windows of today. The original single pane window had an R-value (resistance to heat loss) of one. The addition of the double pane, or thermopane, window after the Second World War gave the window an R-2 rating. Today there are special features like low emissivity (low-E) coating applied to the inside surface that reflects heat back into the building rather than transmitting it outdoors.

These windows have an R-3 rating. Adding a second layer of low-E coating or the addition of various gases between the two sheets of glass achieve further savings. Argon, for example, is a non-toxic gas that gives a window an R-4 rating. In the 1980's a new generation of super window was invented, with the addition of heat mirror films that gave the window an R-6 to R-8 rating. Despite these advances, windows are still poor insulators compared to other building shell insulation measures that attain much higher R values such as, attic wall or floor insulation. However, newer, tighter windows have an added benefit of reducing air infiltration which is a major cause of heat loss in the winter

[34] Tom Woolley and Sam Kimmins., *Green Building Handbook* (London: E & FN Spon, 2000),78.

and heat gain in the summer. Windows are an important consideration in the green-building design in determining how many windows will be operable and used for ventilation purposes.

Adhesives and Sealants

Adhesives come in a vast array of formulations. Historically, they were made from natural materials and were effective in non-structural applications. Synthetic adhesives based on coal and oil were first developed in the 1940's during the Second World War, primarily the formaldehyde adhesives for wood. These synthetic adhesives were polyvinyl acetate-based polymers, and by the 1960's these had become almost the universal adhesive used in the construction industry.[35] Adhesives contain many of the same chemicals as paints and raise some of the same concerns. As with paints, adhesives, sealants, caulks, coatings and finishes are placed in the building when wet and allowed to dry, releasing VOCs in the process. Adhesives affect a wide range of construction materials and can be components of plywood, particleboard, moveable wall panels, and office workstations. One way to characterize adhesives in terms of IAQ is in the resins that are used which can be natural or synthetic. Natural resins have low-emission potential, where formaldehyde resins are more toxic. Because of consumer pressure and government legislation, many of the larger adhesive manufacturers are moving from using solvents in their products, which present the greatest health hazard, to more water-based adhesives which are safer to handle and manufacture.

[35] Tom Woolley and Sam Kimmins, *Green Building Handbook* (London: E&FN Spon, 2000), 44.

Finishes

Finishes comprise a wide range of products including paints, varnishes, stains, and sealers. They serve as protection against corrosion, weathering, and damage and add to the aesthetic value of a building. They require resins and oils to form a film and carriers (water or organic solvents) that give thickness and substance. The amount of solids is a good indicator of the VOC emission potential. The sanding or burning of finishes generates potential IEQ hazards like dust, silica and mica, especially from lead. Water-based finishes are typically low-emitting, which is the current trend to replace conventional finishes. Unfortunately, this is mainly seen in paints because few stains, sealers and varnishes have been successfully adapted for low VOC emissions. Alternative finishes have not performed very well because they may require more applications to achieve similar results of traditional finishes. Despite this, they give an option for designers in achieving better IAQ.

Particleboard and Plywood

Particleboard has multiple uses in the building from core materials for doors, cabinets, and many furnishings, such as table and prefabricated wall systems. It is also used in non-structural floor underlayment. The major IAQ concern is the off-gassing of formaldehyde, and most particleboard contains urea formaldehyde. A small percentage contain phenol-formaldehyde which emits far lower amounts of formaldehyde. Although particleboard can be manufactured with low formaldehyde, it is still of major concern because of large exposed surface areas.

Plywood is classified as hardwood or softwood. Approximately 80% of all softwood plywood is used on wall and roof sheathing, siding, concrete framework, and decking and sub flooring.[36] Hardwood plywood is used for furniture, cabinets, shelving, and interior paneling. The types of adhesives used in bonding plays a critical role in assessing the effects on IAQ. Plywood is generally bonded with urea formaldehyde resins and is compounded by finishes and sealants. However, the new advances in low-emitting formaldehyde offer the green designer a viable alternative to the standard high-emitting products.

Flooring and Wall Coverings

Carpet, flooring and wall coverings traditionally have VOC emitting compounds and use adhesives that emit VOCs. However, products with zero or low emissions are now fortunately entering the marketplace, available for the green building industry. Carpet is the product that has generated the most controversy. Emissions from carpets are generally low when compared to other products, but the majority of emissions are associated with the adhesives that are used to secure it. The other concern with carpets is that the backing is made with materials that can be bonded with styrene rubber, a known irritant to mucous membranes and skin. Adhesive may be used twice, to glue the backing to the carpet fibers and the carpet to the floor. Over the last 20 years, the choices for carpets have expanded. Wool was the carpet of choice in the 1970's. When the price of

[36] Charles Kibert, *Sustainable Construction Green Building Design and Delivery* (New Jersey: John Wiley & Sons, 2005), 332.

wool skyrocketed, manufacturers developed nylon, olefin, polyester and polyethylene which are all synthetic fibers derived from petrochemicals.[37]

Resilient flooring is pliable and flexible and can be made of vinyl, rubber and linoleum. Vinyl flooring is made primarily from polyvinyl chloride (PVC) resins with plasticizers which are the main sources of emissions. Using a more rigid, less plastic tile is recommended to avoid potential hazards. Linoleum is also a good alternative because it is natural, organic, and biodegradable. The main components are linseed oil, rosin, wood flour, cork powder and pigments. It is easily maintained and long lasting. Wall coverings are a good alternative to paints. The majority of coverings present no real threat to IAQ. The main types are paper, fabric and vinyl. Paper itself poses no air quality problems, but the adhesives may contain formaldehyde. The majority of adhesives are a powder mixed with water, and they emit few or no VOCs. Fabrics may be more volatile; they may contain formaldehyde and act as a "sink" by absorbing VOCs in a building and re-emitting them into a space.

Forestry Programs

Since a great deal of wood products are used in the construction industry, there is concern over the supply and how foresters are logging and managing their business. In today's sustainable building movement, there are organizations that are devoted to encouraging the responsible management of the world's forests. In many forests around the world, logging contributes to habitat destruction, water pollution, displacement of indigenous peoples, and violence against people who work in the forests and the wildlife

[37] Charles Kibert, *Sustainable Construction Green Building Design and Delivery* (New Jersey: John Wiley & Sons, 2005), 334.

that dwells there. Many consumers of wood and paper, and many forest products' companies, believe that the link between logging and these negative practices can be broken.[38] The Sustainable Forestry Initiative (SFI) program is a system of principles and performance measures developed by professional foresters and scientists, among others, which combines growing and harvesting of tress with long-term protection of wildlife, plants, soil and water quality.

The Forest Stewardship Council (FSC) certification system ensures that an independent evaluation has been performed on a forest company's practices. This includes checking that the company is practicing forestry in a manner that protects biodiversity, conservation of ancient natural woodlands, responsible management, and forest workers' rights. The FSC is the only system that verifies that certification practices are done from the forest to the product, a process known as "chain of custody" monitoring.[39] It is one way to ensure that companies are working to protect this valuable resource and ensure that the business of forestry does not do unnecessary damage to our environment.

Insulation

Insulation is a critical element in buildings and one of the most important energy conservation measures. Part of a thermally effective and tight building shell relies on high values of insulation in residential as well as commercial buildings. This is because the majority of the surface areas of a typical building are ceilings, floors or walls. These are

[38] FSC-US Issues Prospectus. Forest Stewardship Council United States. http://www.fscus.org/news/archive.php.
[39] Sustainable Industry Building Council, *Green Building Guidelines: Meeting the Demand For Low-Energy Resource-Efficient Homes* (2004), 115.

the areas that can be designed with higher R-values of insulation, thus achieving more energy savings, as seen in super-insulated structures that go above the building code. The question is not how much we should insulate, but we should find the most effective way of insulating each element of the building.

Fiberglass batting is a less expensive option and can contain recycled content materials. Fiberglass and mineral wool have been good insulators, but there are IAQ concerns because of small fibers that are produced when the material is disturbed. Fiberglass is listed by the International Agency for Research for Cancer as a possible carcinogen. Recycled cotton batts are made from recycled blue jean material and contain no IAQ problems. Cotton is a good alternative to fiberglass but is potentially still expensive in today's marketplace. Loose-fill cellulose is made from recycled newspaper and has over 80% recycled content. Cellulose treated with borate is a better option over ammonium sulfate because of less toxicity. It can be used in attics and wet spray in walls and is a good air sealer and considered a nontoxic material.[40]

Ventilation

As mentioned earlier, ventilation is a critical element in today's tighter building construction. If energy-efficient construction is not done properly, it can damage the building and its inhabitants. A carefully controlled ventilation system is needed to exhaust stale air and bring in new air. We need efficient ventilation to dispose of smells, pollution and water vapor. Insufficient removal of water vapor can cause mold buildup

[40] Sustainable Industry Building Council, *Green Building Guidelines: Meeting the Demand For Low-Energy Resource-Efficient Homes* (2004), 118.

and eventually damage the interior surface material, also causing considerable health hazards for the occupants.

One of the most effective ways to minimize pollutants is by source control. That is, identify the pollutant sources such as products, equipment and furnishings, and reduce or eliminate them to produce a healthier indoor environment. Besides pollutants from materials and furnishings, un-vented combustion appliances used for space heating can create unwanted gases. In a tight home, combustion appliances can "backdraft," meaning gases do not go up the flue or out the vent, but are discharged into the house. That is why proper balancing of ventilation and makeup air is necessary for the right amount of air exchange in tighter-built buildings in today's construction industry. Appropriate ventilation can be achieved by spot ventilation, opening a window in a room that is heavily used, heat recovery ventilation, and efficient whole house ventilation.

Having effective ventilation control is also paramount. In commercial buildings it is important to review building occupant needs, evaluate the HVAC system and facilitate maintenance and cleaning of the HVAC system to reduce airborne pollutants. Besides active ventilation systems, effective green design incorporates passive cooling, or natural ventilation. For example, this can be accomplished by the proper placement of windows where some windows are set at lower levels and some at higher levels so the incoming and outgoing air create a pressure difference and cause the air to move throughout the building.

Designers need to strike a balance between sealing up buildings to conserve energy and obtaining the necessary ventilation rate for the building and the occupants. This is essential because some pollutants themselves, such as moisture and mold, not only affect

the occupants but are detrimental to the building structure itself. Buildings have traditionally depended on the leakiness of the construction to provide a certain level of background ventilation, or infiltration. The problem with this is that the actual amount of ventilation from infiltration depends on the current external wind speed and the internal/external temperature differences. So the key is to reduce the background leakiness and have carefully positioned openings, either passive or fan-assisted, that can be opened and closed at will.[41]

Although much is known about the health effects of poor design and the ways to overcome them, much research is still needed in this field. Several entities have undertaken considerable effort to further the research and science in air quality, including governmental agencies such as the U.S. Environmental Protection Agency (EPA), the National Institute of Occupational Safety and Health (NIOSH), and Occupational Safety and Health Administration (OSHA). Other professional organizations such as the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) are also doing research that will lead to more definite IAQ practices.[42]

[41] Tom Woolley and Sam Kimmons, *Green Building Handbook* (London: E&FN Spon, 2000), 110.
[42] Anthony Bernheim, *Sustainable Building Technical Manual: Green Building Design, Construction and Operations* (USA: Public Technology Inc., 1996), 89.

Chapter 7

DELIVERY SYSTEMS

One of the major components of building development is the organization and management of projects. This involves an intricate network of players who bring various professional expertise together in a unified team to bring a project to fruition. The traditional construction development process does not foster collaboration with the different professional disciplines, and it has no consideration of sustainable design strategies. It is most familiar to owners and designers because it has been around for a long time and is a well understood method.

Design-Bid-Build

Conventional delivery systems in the United States fall into different categories. The design-bid-build system sets the owner as the managing focal point of a project. The owner holds separate contracts with the architect and the builder, and there is no direct contractual relationship between the architect and builder. Therefore, they virtually operate independent of one another, and communication about the project is not integrated. The owner's responsibilities include determining the goals and requirements of the project, acquiring a usable site for the intended purposes, financing the project, directing both the architect and contractor, and resolving issues between the architect and contractor.

The owner is responsible for the overall project management functions. If the owner chooses so, the architect or contractor can assume these duties. The architect and

contractor are responsible for managing the design and construction processes accordingly.

The designer does the pre-design and assists the owner to determine the goals and requirements of the project, acting as coordinating consultant. The designer ensures regulatory and code compliance and develops all the construction documents; duties can also include assisting with construction bidding and negotiations. The contractor works independently of the development process but is generally committed to the overall goal and cost of construction. The designer and owner prepare the necessary submittals to accomplish the work, providing the methods and means of construction. In the overall format of the traditional construction process, the contractor is not involved in developing the details and vision of the project as set forth by the owner and architect.

From the owner's perspective, the traditional process is well understood and provides a degree of reliability in relation to design quality and a desired outcome. Some owners may prefer this method because they are direct participants throughout the design process, but there is a disadvantage in leaving the contractors out of the process because they might have valuable input as to the nature and methods of construction for a particular project and how it could affect the design process. There are various pros and cons to the traditional method as outlined below. (Figure 7.1). [43]

[43] Darlene Septelka, "Design Build Project Management." *Washington State University Spokane Arch 520.3 class publishing Spring Semester 2001,* 7-8.

Design-Bid-Build

Pros

- The linear process is easy for owners to manage and understand.
- Owners can actively participate in the design process.
- Once the contractor makes a cost commitment, it is usually reliable since it is based on relatively complete design documents.
- Design and construction roles are separate and well understood, making both responsibility and liability relatively clear.
- Owners have the opportunity to review competitive bids for construction costs.
- Contractors are familiar with this process and work well under its constraints.

Cons

- The cost of construction is not firmly established until design is complete.
- If bids run over budget, redesign, value engineering and re-bidding can lead to project delays and additional design costs.
- The architect does not typically receive the benefit of the contractor's advice on constructability and cost during the design phase.
- Too often it is based on the premise that architects can produce an unrealistically perfect set of construction documents.
- Since most contractor's compete on the basis of low bid, any gaps or alterations in the design documents have the possibility to become opportunities for contractor delay claims and change orders.
- Adversary relationships and the potential for litigation can develop between architect and contractor due to their separate contracts with the owner and the low-bidding contractor's overriding interest in cost.

(Figure 7.1 Design-bid-build pros and cons)

As mentioned above, this process is linear, the independence of two primary players, the architect and contractor, and the aggressive low bidding by the contractor can foster an adversarial relationship between the two. The traditional process may have some advantages, but it lacks the coherence of a more integrated approach.

Construction Management

In this system the owner contracts separately with the design team and the contractor or construction manager (CM). It is also referred to as "negotiated work" since the construction manager negotiates a fee for providing management services to the owner. In the early design stage the construction manager establishes the cost of construction through a guaranteed maximum price (GMP). When selected early, the construction manager can provide pre-construction planning, cost analysis, value engineering and scheduling. Working together with the architect, the parties produce construction documents that meet the owner's requirements, schedule and budget. This in turn should help minimize conflicts, missing information and miscommunication often found in the construction documents in the design-bid-build process.

The construction manager is then involved in construction procurement and execution using a bidding process, selecting subcontractors based on their capabilities and the quality of work, not just the lowest bid. The level of conflict in this type of delivery system is much lower because of the closer relationship among the parties to the contract.

The owners with less experience, or lacking in-house experience can benefit from having the CM act as a middle man. The management burden on the owner's staff is also reduced. Other positive aspects include construction cost estimates during the design phase allow construction to be monitored at an early phase, the skills of the CM allows some owners to fast track some aspects of a project, and the system is familiar and easy to manage.

On the other hand there can be some downfalls to this type of system. Overlapping areas of expertise can confuse traditional roles, complicate practices and increase time and paperwork required to complete a project. Costs are also increased for management and design services when compared to traditional delivery methods. Construction Management can act as a communication filter with the owner, and can result in reduced owner participation.

If the CMs act as contractor, he can make a cost commitment early in the project. They are then committed to deliver the project at a certain price, and then motivated to complete the project as soon as possible. This process can lend itself to fast-tracking some aspects of the project because design problems can be worked out early on in the project. On the downside the owner may lose some aspect of control by not having direct management of the project.[44]

Design Build

Considering that the construction management negotiated work reduces the frequency and level of conflicts that are present in design-bid-build, tension between the design team and the construction manager can still exist. The design-build delivery system provides the owner with a single contractual relationship with a separate entity that combines both the design and construction services. This can be a firm that incorporates in-house design and construction capabilities. It could also involve a partnership between a design firm and a construction firm. The advantage to the owner is one-point responsibility and time savings in exchange for the loss of direct project

[44] Darlene Septelka, "Design Build Project Management." *Washington State University Spokane Arch 520.3 class publishing's Spring 2001,* 15.

control. This system is preferable when the owner needs an early cost commitment or if it is a complex project requiring close coordination of design and construction expertise. It can also be advantageous when the owner wishes to fast track the project. The owner is responsible to determine the goals and requirements for the project, acquire a useable site, finance the project, and direct the design-build team. The owners are also responsible for management, although they may choose to pass some of the project management responsibilities to the design-build contract. -

The design-build team is generally responsible for developing the design for the project within the budget commitments, acquiring permits, dealing with regulatory concerns and code compliance, and preparing cost estimates and construction documents. The DB team is thus responsible for the construction. It is important that they guarantee the actual cost of construction, maintain the construction schedule, and manage purchasing and subcontracting.

One positive aspect of this type of system is that there is a single-point responsibility for design and construction. Interactions between parties are better coordinated which saves time. This can be a faster delivery system allowing the owner to benefit financially. Time delays due to scheduling problems and changes in construction are reduced as well as change orders. Also, conflicts between the project professionals are internalized within the DB entity, and do not involve the owner.

The downside of this type of delivery system is that it is not as well understood as the design-bid-build system; it can be more complex and less clear to owners. Also, owners with less experience are likely to have difficulty utilizing this method. Other considerations are that the architect does not serve directly as the owner's agent which

shifts some aspect of loyalty away from the owner, and design changes by the owner can carry added costs. Within the design-build system, deliberations about cost-saving strategies can take place which can lead to a reduction in building quality without input from the owner.[45] Each system carries the possibility of a successful project while having its own concerns and complications. The DB system can be more beneficial because communication is improved and design and construction issues are usually worked out in the front end, minimizing surprises at the tail end. This type of system is more likely to minimize typical design-construction conflicts, provide a more economical price for the owner, improve quality, and speed the project to completion.

High Performance Green Building Delivery

Green building design has some characteristics of the design-build delivery system, but sets forth a different ideal for owners and industry professionals. It initiates a new process for design and development that is inherently more cohesive, drawing the owner, architect, builder and other industry professionals into a more unified relationship. It requires a great deal of communication among the project team members. As a result, the initial "team building" ensures that everyone understands the project's goals and the unique specifications. This delivery system demands special cooperation from participants in the understanding of and commitment to the concept of green building. It especially requires a familiarity with details if the project is going to be LEED certified.

This "whole-system" building design considers site, energy, materials, indoor air quality, acoustics, natural resources and the interrelationship to one another. This

[45] Darlene Septelka, "Design Build Project Management," *Washington State University Spokane Arch 520.3 class publishing's Spring 2001,* 20.

collaboration of players utilizes system thinking to consider the building structure and systems holistically. Having an integrated design approach to green building is crucial; it can be considered "a process by which all of the design variables that affect one another are considered together and resolved in an optimal fashion."[46] One example of this is the advanced day-lighting strategy which reduces the use of lighting fixtures during daylight, thereby reducing cooling peak loads, justifying a reduction in the mechanical cooling system.

As mentioned earlier, the traditional design-bid-build design process supports a system where all the parties involved essentially work in isolation. To this extent they maintain control of the specific part of the process that they are working on. This system does not foster effective collaboration or sustainable design strategies.

For integrated design to succeed, it is essential that the isolation effect of the traditional method be overcome in two ways:

1. That the various parties and disciplines communicate and interact with each other collaboratively and creatively, and
2. That the different disciplines utilize whole systems thinking throughout the entire project.

[46] Malcolm Lewis, "Integrated Design For Sustainable Buildings," *ASHRAE Journal*, Sept. 2004, 22

Communication Strategy

- Setting goals for performance
- Getting all team members involved early
- Conducting design charettes
- Performing project review/peer review
- Establishing work groups on specific issues(i.e., green design)
- Using building system commissioning as a project process

Probably the most critical element of the design process is promoting effective communicaton.(Figure 7.2) The integrated design process begins with the design phases but continues throughout the entire project life. Once the building has been designed it must be constructed, commissioned and operated in a

(Figure 7.2 Communication strategy) way that supports the integrated green building concepts for which it was planned. If it is not first designed with green features in mind, it will never achieve the desired result which is why there needs to be an overall project plan and a commitment to achieving a high level of sustainability. This starts with the owner and decision makers. Without this commitment it isn't likely that the full potential will be reached as other issues may come up that will offset the sustainable objectives for the project. Once the commitment is made, goals and strategies come into play. Goals should be explicit and measurable. For example, this can be as general as achieving a LEED rating of silver or better, or reducing environmental impacts from wastewater, solid waste by a certain percentage below the standard practice.[47]

Once the goals have been set, the integrated design process will lead to strategies to achieve those goals. This typically can be in the setting of brainstorming sessions such as a design charette or workshop where the entire project team participates. Everyone is represented to foster an environment where ideas and concepts can be maximized. When

[47] Malcolm Lewis, "Integrated Design For Sustainable Buildings," *ASHRAE Journal, Sept. 2004*, 23.

a set of strategy options is developed, analysis is important. For example, assessing the heating and cooling loads necessary for a particular building design and climate enables the HVAC systems to be properly sized for cost effectiveness which involves selecting options with the best economic performance.

Another element of this process is to have follow-through to implement sustainable strategies effectively. These actions help make sure that the project stays focused on delivering the desired performance stated in the project goals. Other actions can include peer reviews and documentation of sustainability measures as required by the U. S. Green Building Council's LEED program.

The Owner

The roles of all the project team (owner, designer, builder and operator) are essential to the success of the project. All disciplines in all the project phases are affected by the sustainability goals. The owner is the most critical of the participants in making a green building happen. If the owner is not committed, the design, construction and operations teams will not receive the support and guidance they will need to accomplish the goals. The owner's specific activities can include establishing the basic value system, selecting the team, setting budgets and schedules, and maintaining commitment throughout the project. It may be difficult for the owner to find a green architect because some architects may be unsure about making the step toward sustainable architecture. They may think that they are moving into untested territories. However, smart buildings, green products and sustainable architecture are tested and implemented technologies.

The Architect

The majority of building projects in residential and commercial today are still done using conventional design methods. Projects for high performance building represent a smaller fraction of architectural commission's. Such jobs that are being done require a high level alliance with the client and the architect. Architects have varied backgrounds. Some have an international design reputation, and some have regional practices with residential and commercial clients concerned about the sick building syndrome that want to make a significant change in their new building environment. In any case, finding an architect with green building experience may be difficult to accomplish. The architect is the second most vital element in the team.

The architect's role becomes very specific. The design team sets sustainability goals of energy use, materials selection, systems integration and environmental impact minimization. Their role also requires them to follow the design optimization plan, perform the commissioning of the building, training the building operators, doing post-occupancy evaluations and providing feedback.

The Builder

The builder is the next most critical player of the team. Whether an owner wants to build a house or construct a commercial building, finding a builder with experience in green building can be equally challenging. Some builders may have an awareness and concern for sustainable principles, which will help in building the teamwork necessary for achieving green building goals. In any case, it is important for the owner and

designer to educate the other members of the team if they lack experience so the goals are well defined and clearly understood.

For example, many builders are used to building for the fewest dollars per square foot. For them, spending additional money for special green measures that do the same task as cheaper non-green measures is a difficult idea to accept. The owner and architect must explain to the builder why items were specified, and the willingness to pay extra for them.

Once selected, the contractor's role is to ensure that all trades understand their job site sustainability responsibilities. The contractor needs to monitor and document sustainable activities, cooperate with commissioning authorities in commercial developments, and control the compliance with specifications regarding sustainability. Operation's role then is to train building operators in all sustainability-related systems.

The Engineer

The role of the engineer in the green design process can be expanded beyond the somewhat limited role in the traditional process. For example, there is the recognition that the design process requires design alternatives which must be refined and evaluated and maximized collaboratively with other design disciplines.

The engineer's role will be expanded because the process encourages discussion among the project team of how to achieve production goals, system by system. It also leads to documentation of the design intent for the systems being designed as a basis for future reference during construction.

Another element with regard to the expanded role of the engineer is that it will lead to mechanisms for verifying that the design intent is met throughout the project. In design this may include peer review and system coordination between design disciplines. In construction, it can include performing commissioning of building systems. In operations it can include providing training to building operators so they know how the systems are intended to operate, and performing energy and water audits of the building to correlate with design parameters.

Finally, the key features of green buildings are the innovative systems that require a lot of coordination among disciplines. Examples of this in commercial buildings include day lighting strategies, under floor air distribution, natural ventilation, and radiant cooling. These systems require the engineer to take a leading role in defining the design requirements if a successful design is to be achieved.[48]

[48] Malcolm Lewis, "Integrated Design For Sustainable Buildings," *ASHRAE Journal*, Sept. 2004, 26.

Chapter 8

BUILDING ECONOMICS

The high performance green building movement involves a complex process that has been expanding rapidly, especially in the past several years. As recently as three or four years ago, the feasibility of designing and constructing projects under the USGBC LEED rating program was in doubt. Most industry professionals were concerned with whether they could achieve the goals of LEED, if new products would be available, and whether green building would cost more than comparable, conventional projects.[49] In recent years these concerns have been put to rest. Many building teams have gained experience and knowledge and are able to achieve a basic rating under the LEED protocols.

Other questions are under consideration with green buildings. Are they profitable? Do they create more value in the real estate market? Are green buildings provide a healthier more productive environment for occupants than conventional buildings? This chapter will address these issues with the attempt to make a case for the economic aspects of green building, that there are more enhanced benefits compared to conventional building. As mentioned earlier, there is the increased demand for natural resources for building development, and the concern of having enough to meet that demand. Developing countries, such as China and India, are growing at an accelerated pace which is resulting in shortages and high prices for materials and agricultural products. The green building movement is bringing about the awareness that there is a need to design

[49] Green Buildings And The Bottom Line. Building Design and Construction. November 2006. http://www.bdcnetwork.com/contents/pdfs/whiitepaper06.pdf.

buildings to be more resource efficient, and lessen the impact on waste and foster new ideas for recycle and reuse of materials. The development of green building involves many facets including life cycle assessments, life cycle costs, embodied energy, and the savings to investment forecast of incorporating green design into a project.

Life-cycle assessment (LCA) is a method for determining the environmental and resource impacts of a material, product, or entire building over its service life. The life cycle, or time period in this example, can cover the extraction of resources, the manufacturing process, installation in a building and the item's eventual disposal. The assessment also considers the resources needed to transport components from extraction through disposal, or cradle to grave. LCA's comprehensive approach examines all impacts of material selection decisions rather than just the item's performance in a building. For example, trees produce paper which is recycled into low energy production cellulose (fiberised paper) insulation, then used as a home energy savings measure in the ceiling of a home for 40 years. The result is saving 2000 times the fossil fuel used in its production.[50]

Life-cycle costing (LCC) is the ability to model a building's financial performance over its life cycle. It is necessary to justify measures that may require greater initial capital investment, but can substantially lower operational costs over time. In LCC a cost benefit analysis is performed for each year of the expected life of the building. Net benefits are calculated to ascertain the present worth of a particular feature. For example, the financial return for installing a photovoltaic system (solar cell array that generates electricity) would be determined by amortizing the system's cost over its probable life;

[50] Life Cycle Assessment. Wikipedia The Free Encyclopedia. http://en.wikipedia.org/wiki/life_cycle_assessment, April 20, 2007.

then the worth of the energy generated each year would be calculated to determine the net annual benefit. The most challenging task of an LCC is to determine the economic effects of alternative designs for buildings and systems and to quantify these effects. There are numerous costs associated with acquiring, operating, maintaining and disposing of a building or system. Costs are most relevant when they differ from one alternative compared to another, which causes a good deal of uncertainty when making decisions about building related investments. But an LCC greatly increases the likelihood of choosing a project that saves money in the long run.[51]

Embodied energy refers to the total energy consumed in the acquisition and processing of raw materials, manufacturing, transportation, installation, and ultimate reuse of a product. Products with higher embodied energy usually have higher environmental impacts due to the emissions and greenhouse gases associated with energy consumption. More durable products will have lower embodied energy over time. For example, a product such as aluminum has a higher embodied energy initially, but will have a lower embodied energy per time because of its very high durability and potential for recycling. Also, certain materials have lower embodied energy when recycled, because it requires less energy to make new products from recycled material than to manufacture new ones from new resources.[52] All these factors have an effect on the green building movement and defining new directions for design and construction of the built environment.

[51] Fuller, Sieglinde. "Life Cycle Cost Analysis (LCCA)." Whole Building Design Guide. Feb.26, 2007: 1-3. http://www.wbdg.org/design/lcaa.php.
[52] Charles J. Kibert, *Sustainable Construction Green Building Design and Delivery* (New Jersey: Wiley and Sons, 2005), 44.

Building economics is important to understand in any construction project but is especially important for high performance green buildings. The question is, does it make good economic sense? Some say it does, others may disagree because of cost constraints and regulatory factors.

There are different schools of thought when it comes to the economics of green building. One school can say that the overall construction costs of these green buildings should be the same or lower than conventional buildings. The main crux of this school is that through integrated design and reducing the size of mechanical systems to heat and cool an energy efficient building, the costs can be kept in line with those of conventional building construction.

In contrast, another outlook is that green buildings will inevitably have higher costs, but assessing total building costs on a life cycle basis, the advantages of high performance building will achieve savings. Others may insist that green building is by far more expensive and will deter owners from pursuing this course, and will inhibit potential clients from getting involved. In fact, high performance buildings can produce benefits for owners in different ways, including energy and water conservation, wastewater reduction, and improvements in health and productivity.

A recent study of the California Sustainable Building Task Force states that a two percent additional investment to build a high performance building would produce a life cycle savings 10 times greater than the initial investment. For example, an additional $100,000 investment in a $5 million dollar building should produce at least $1 million dollars in savings for a building with an assumed 20 year life cycle.[53]

[53] Charles J. Kibert, *Sustainable Construction Green Building Design and Delivery* (New Jersey: Wiley and Sons, 2005),375.

The jury is out on whether green buildings have higher capital or construction costs, than comparable construction projects. According to the California study, there are varying views of this that range from 2% to 20% of added costs depending on the degree of green measure incorporated in the building and the level of LEED certification, if owners choose to pursue that goal. On the low side, the 2% cost equates to $2 to $5 per square foot. The following information shows the approximate increase in costs for the different levels of LEED certification. (Figure 8.1)

LEED Rating	Sample Size	Cost Premium
Platinum	1	6.50%
Gold	6	1.82%
Silver	18	2.11%
Certified	8	0.66%
Average	__	1.84%

(Figure 8.1 Increased cost for LEED buildings)

This, however, may not always be relevant in LEED building projects. A recent alternate study was done by Davis Langdon and Associates on 45 library, laboratory, and academic classroom projects which were designed to meet a certain level of LEED certification. They compared them with 93 non-LEED buildings with similar measures. The results showed that there was no statistically significant difference in cost per square foot of the LEED and non-LEED population. Projects are achieving LEED within the

same cost range as non-LEED buildings. That doesn't mean that a specific building can achieve LEED with no additional cost. There are many factors that affect the cost of a building, but LEED can have a lesser impact than other factors. The projects that were most successful in remaining within their original budgets were those which had clear goals established from the start, and which integrated the sustainable elements early in the project.[54]

The California Sustainable Building study on high performance green building concluded that there are significant economic benefits associated with the LEED rating system and the financial return. For a typical high performance building the total net present value (TNPV) of the energy savings over a 20-year life cycle is $5.79 per square foot. Net present value (NPV) is the net savings for the life of the project. The TNPV is the sum of the NPV's for all 20 years and represents the total life-cycle savings. Also, health and productivity for LEED Certified and Silver projects showed a savings of $36.89 per square foot. For LEED Gold and Platinum it showed a savings of $55.33 per square foot. It is clear that health and productivity outpaces that of energy and other sectors. However, it is important to note that these claims may be accepted among high performance building professionals, but are not necessarily based on scientific evidence.[55]

Do green buildings create more value than conventional buildings? A recent study shows that from a market valuation perspective, we are starting to see things turn a little bit. Lee Smith, president of Hartland Asset Management, a Scarsdale N.Y. real estate

[54] Davis Langdon, "Examining The Cost of Green," *Lisa Fay Matthiessen AIA, LEED AP*, October 2004, 2-3.
[55] Charles J. Kibert, *Sustainable Construction Green Building Design and Delivery*. (New Jersey: Wiley and Sons, 2005), 48.

investment fund, says value is in the eye of the beholder. "People will tell you 'green' increases the reputation of your building and the health of the tenants, but we've gone past that stage, and now they're being sold on economic value."[56] One study on green buildings' bottom line, done by the Canadian Branch of the Royal Institute of Chartered Surveyors, started with the hypothesis that there is no relationship between the market values of real estate, and its green features and related performance. But, the study disproved this and showed that they did find value, not primarily in energy savings from more efficient design but in business productivity and output.[57]

Other reasons for significant net savings in some commercial buildings can be seen in areas like building commissioning. Building commissioning is the check and balancing procedure to see that all systems are functioning as designed. The more efficient and in sync systems run, the greater the energy savings. Other features may include natural landscaping and the use of easily-maintained, drought-tolerant plants requiring less potable city water. Utilizing raised floors and movable walls in commercial buildings produces savings by improving the flexibility of a building's interior, reducing renovation costs. The elements described are some of the features of high performance buildings that can produce savings with a relatively short pay back.

Additional higher costs can be associated with high performance green buildings because of different design and systems, as mentioned earlier. One is recapturing rainwater for use in irrigation, and gray water recycling used to flush toilets. Others include daylight-integrated lighting controls and energy recovery ventilators, to name a few. Also, green building certification (fees, preparation of documents, cost of

[56] Green Building The Bottom Line. Building Design +Construction. November 2006. http://www.bdcnetwork.com/contents/pdfs/whitepaper06.pdf.11.
[57] Ibid., 11.

consultants) can add significantly to the cost of a project. Finally, many green building products can cost more than their counterparts, partly because some are new to the marketplace and the demand may not be high. In this category are many non-toxic materials (paints, adhesives, floor coverings), linoleum and pressed strawboard for example. On the other hand, cost reductions for some building systems are possible, such as HVAC systems that can be downsized because of improved building envelope design. These types of changes can offset the extra front- end cost of green measures, and may result in very little difference, if any, in green building design as compared to a comparable conventional project.

According to the study done on green buildings for the State of California, it becomes more evident that costs go down as we learn more about green buildings. Over a 20-year period for a certified LEED silver building there would be approximately 10 times the return on investment. A higher level of green design and sustainability brings a bigger payback. About 70% of the benefits come from improvements in health and productivity.[58] This shows that one of the main investments for the building owner is in the employees of the company and not just in the structure itself.

However, making a case for high-performance buildings in the private sector involves a justification of why they make good business sense. In 2003 the USGBC attempted to address this issue by producing a brochure entitled, "Making the Business Case for High Performance Buildings;" it addresses the advantages to a business of selecting green buildings over conventional facilities. Some of the results of the study state that green buildings:

[58] Economics of Green Building. Greater Vancouver Regional District. June 10-11 2004. http://www.sfu.ca/city/PDFs/summary June10-1104.pdf.

1. Recover higher first costs – Using integrated design can reduce first costs, and higher costs for technology can reap rapid benefits.
2. Are designed for cost effectiveness – Owners are experiencing significant savings ranging from 20 to 50 percent, also saving in building maintenance, landscaping and water.
3. Boost employee productivity – Increased daylight, pleasant views, and better sound control can reduce absenteeism, improve health, and boost worker productivity.
4. Enhance health and well being – Improved indoor environments can translate into better results in hiring and retaining employees.
5. Reduce liability – Eliminating the sick building effect and problems such as mold can reduce incidents of claims and litigation.
6. Increase property value – A strategy of LEED –NC rating system is to differentiate green buildings in the marketplace with the assumption that lower operation costs and better indoor environmental quality will result in higher values in the marketplace. A building with a LEED rating will imply superior operational and health performance, and buyers will be inspired to pay a premium for these features.
7. Benefit your community – Green buildings emphasize infill development, recycling, bicycle use, and measures that reduce environmental impact, improve the local economy and foster stronger neighborhoods. Businesses opting for

green building will be contributing to the quality of life in the community and earn a better reputation for their efforts.[59]

Besides these factors, other benefits can be claimed for high performance buildings. These can include addressing other issues, such as reducing the rising incidences of allergies and asthma, and the positive effect of school environment on children's ability to learn in educational settings as shown in the Heschong Mahone Group's research discussed later in this chapter.

Energy Efficiency

In building operation, the goal is to minimize use of electricity and fuels like natural gas for space heating and cooling, water heating, appliances and lighting. In addition to cost savings, these practices reduce pollution and environmental damage, caused by extraction, production and transport. In transportation, the goal is to minimize excessive auto transportation by providing alternatives where walking and bicycling to work, stores and schools saves energy and reduces pollution.[60]

Green buildings use considerably less energy than conventional buildings and can generate some power on-site from alternative energy sources such as photovoltaics. This in turn reduces fossil fuel based energy consumption up to 30 percent in some cases.[61] Analyzing the energy advantages of green buildings requires the use of energy simulation tools. Various alternatives can be tried and tested to determine the best combination for a particular building and site. An LCC analysis is done at the same time to determine the

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[59] Charles J. Kibert, *Sustainable Construction Green Building design and Construction* (New Jersey: Wiley and Sons, 2005), 47.
[60] Michael O'Brien and Debbi Palermini., *Guide To Resource Efficient Building.* (Portland, Oregon: 1993), 5.
[61] Ibid., 6.

cost and payback information. With this approach, first costs and operation costs are used to give an overall view of the building's energy performance over an assumed lifetime.

So much energy is consumed in buildings. In the commercial sector, approximately 50 percent of energy is used to create an artificial indoor climate through heating, cooling, ventilation and lighting. A typical building's energy bill constitutes approximately 25 percent of the building's total operating costs. Estimates indicate that certain design changes in heating and cooling systems could cut HVAC energy consumption by 60 percent and lighting requirements by at least 50 percent in U.S. buildings.[62] Returns on investments can be higher than rates of return on conventional high yield investments. For example, the Environmental Protection Agency (EPA) has a Green Light Program for lighting. Participants in this program have enjoyed annual rates of return of over 30 percent for lighting retrofits.

Water Efficiency

Water conservation and efficiency programs have begun to lead to substantial decreases in the use of water in buildings. Water efficient appliances and fixtures can reduce consumption up to 30% or more. This can be in the form of low flow fixtures, electronic dispensed faucets and waterless urinals. This can be inspired by local water utilities that offer incentives and rebates. As Figure 8.2 reveals, for a typical 100,000 square foot office building, a 30 percent reduction in water usage through the installation

[62] David Gottfried., *Sustainable Building Technical Manual Green Building Design, Construction and Operations.* (United States: Public Technology Inc., 1996), 2.

of efficiency measures can result in annual savings of $4,394. The payback period is 2.5 years on the installed conservation and efficiency measures.[63]

Water Efficiency
In a typical 100,000 sq.ft. office building

Water usage	
Number of Building Occupants	650
Water Use per occupant per Day	20
Total Annual Building Water Use (gallons)	3,250,000
Total Annual Building Water Use (HCF*)	4,345
Water Cost	
Water Cost per HCF	$1.44
Sewer Cost per HCF	$1.93
Total (water + sewer) Cost per HCF	$3.37
Total (water + sewer) Annual Cost	$14,643
Savings	
Initial Cost of Water Measures **	$10,983
Annual Water Conservation at 30% Reduction (HCF)	1,304
Annual Water + Sewer Savings (1,304 HCF at $3.37)	$4,394
Payback Period	2.5 years

* One hundred cubic feet (HCF) = 748 gallons

** Measure includes efficient, low-flow appliances and fixtures as well as control sensors

(Figure 8.2 Water usage and savings in an office building)

Demand on water will increase with urban growth, so will the economic impact of water conservation and efficiency. Water efficiency can lead to substantial water savings, and in turn reduce the requirement for expansion of water treatment facilities. Non-residential water customers comprise a small percentage of the total number of

[63] Ibid., 3.

water customers, but use approximately 35 percent or more of total water consumption. When combined with the residential sector, water consumption represents a great demand on one of our most valuable resources. It is inevitable that we must continue to take the necessary steps in conserving water for the future. Constructing high performance green buildings and retrofitting existing ones is one way to achieve this goal.

Waste Reduction

Waste reduction, up until recently, was not given a great deal of planning and forethought on how to deal with the vast amount of waste generated from construction projects. Large amounts of waste from residential and commercial construction have been shipped to landfills, many of which are at capacity, adding significant costs to jobs for contractors. Of the estimated 20,000 landfills located within the United States, more than 15,000 have reached capacity and closed, and many are following this pattern every year. Construction related waste accounts for more than 25 percent of landfill content and equals total municipal garbage waste generated in the United States.[64] Because of this, an increasing number of landfills will not permit, or will charge extra for, the dumping of construction related waste. In response to this, recycling of this debris is increasing at the job site. It is especially prevalent on green building projects where recycling and minimizing waste is one of the priorities.

Material such as gypsum board, glass, carpet, aluminum, steel, brick, and disassembled building components can be reused or recycled. In addition to construction waste recycling, the building industry is beginning to achieve significant waste reduction

[64] David Gottfried, *Sustainable Building Technical Manual Green Building Design, Construction and* Operations (United States: Public Technology Inc. 1996), 5.

through more building reuse and adaptation rather than demolition. This is another principle of green building: to reuse if possible, instead of creating vast amounts of waste. With ingenuity other structures can be successfully renovated into cost-effective and efficient new structures.

One of the best examples of the savings potential of recycling of construction waste is the Portland Trailblazers Rose Garden Arena, a 75,000 square foot stadium built in Portland, Oregon in 1995. An old stadium and adjacent building were demolished; the project contractor was able to successfully divert the majority of the construction and demolition debris from landfills. This included 1,300 tons of wood, 1,000 tons of metal, and 29 tons of cardboard through reuse and recycling. Also, the contractor diverted large quantities of gypsum wallboard, concrete and asphalt for a recycled cost of only $19,000. This avoided an estimated $166,000 in landfill costs. Rebates totaling $39,000 were received from third party vendors for the metal and cardboard. The resulting net savings from the project for the recycling effort was $186,000.[65]

This is an example of how the application of green building concepts can yield savings during the construction process. Contractors can achieve saving results by implementing measures that are relatively easy. This can include installing efficient lamps and light fixtures, reduced water consumption from reusing storm water or gray water, lowering site clearing costs by minimizing site disruption, lowering landfill dumping fees as discussed earlier, and lowering material costs with more careful purchase and reuse of resources and materials. Another added benefit to implementing

[65] David Gottfried, *Sustainable Building Technical Manual Green Building Design, Construction and* Operations (United States: Public Technology Inc. 1996), 6.

green building features is fewer employee health problems resulting from poor indoor air quality, as will be discussed later.

Building Operation and Maintenance

The various green building measures discussed in this report not only lead to lower building and operating expenses through such things as reduced waste disposal costs, but also to lowering on-going building maintenance costs ranging from salaries to supplies. For example, in office buildings with many floors, maintenance staff collect recycled materials on each floor and by employees' desks, and carry the material down to the basement for sorting. Recycling chutes allow direct discarding of materials from any floor. The chute system, ideally installed during initial construction or renovation, can sort materials automatically, saving labor costs. Other savings can come in the form of reduced elevator maintenance and less frequent cleaning of spills on carpets and floors.

Environmentally friendly housecleaning products can also achieve financial savings. For example, cleaning products that are purchased as concentrates and use minimal packaging promote waste reduction, but can reduce product usage by using dispensers that accurately measure and dilute the product. Building managers and staff must be viewed by the owners as vital participants in sound and cost effective operations. Once the building is operational, the training of management and maintenance staff, and education on green building measures will help them maintain the building in a resource efficient and economical manner.

Health and Productivity Benefits

Do green buildings enhance employee health and performance? Factoring in human benefits into a life cycle cost analysis of a building must by done cautiously. Health and productivity benefits of green buildings are not as easily identified as hard costs like electricity, natural gas, water and solid waste, because it is hard to quantify. The indirect benefits of green buildings benefit the developers and the tenants in different ways. Green buildings may include the following:

- Healthier to use
- Have psychological advantages
- Enhance company image

The use of more natural sources of light, solar energy for heating, and more organic materials used in construction can result in a healthier building as compared to a typical air-conditioned office or university building. The use of natural materials, finishes and designs that are more in tune with the surroundings tend to result in lower levels of sickness and absenteeism. This has obvious advantages in the efficiency of work and productivity, and the effects on a company's balance sheet. In university environments, healthy low energy buildings result in contented students and attraction of good quality academic staff.

Researchers at Carnegie Mellon University have screened hundreds of studies related to the health and human benefits of green buildings. They found that case studies of high performance ventilation systems show reductions in illnesses, including asthma and allergies of 10 to 90%. Thirteen studies suggested individual productivity gains from HVAC improvements. Fourteen studies linked temperature control to performance gains

of 0.2 -7%. Twelve studies indicated that improved lighting design enhances individual productivity between 0.7 to 23%.[66]

People feel "better" in green buildings. They are not only healthy, but they claim a general sense of wellbeing. The ability to open windows, activate their own blinds and pass through well planted atriums or winter gardens, having trees planted outside their windows, all lead to a sense of feeling better about work. In the United States research has shown that the "feel good" factor of green design has improved workplace performance enough to pay for a typical building's annual energy bill. A 1% reduction in absenteeism could pay for the annual energy costs of a typical commercial building. [67]

As described earlier, green design is normally the result of holistic thinking by a group of professionals, including the client, who share similar sustainable ideals. The design team juggles with capital and on-going costs on one hand, and balances energy use, environmental impact and ecology on the other. Having an open view of design allows this to happen and will influence the company that uses it. Consequently, the building leads to subtle changes in the culture of the company and the outlook of the workers. For example, the Body Shop's green outlook influences its products, processes and building procurement which in turn have an impact on the workers and suppliers of the company. This outlook spreads throughout the company, thereby enhancing its image.

Buildings therefore provide many benefits to owners, tenants and employers. Major benefits that have been cited are impressive. For example, a paper by William J. Fisk of the Indoor Environmental Department at Lawrence Berkeley Laboratory notes that

[66] Green Buildings and the Bottom Line. Building Design +Construction. November 2006. http://www.bdcnetwork.com/contents/pdfs/whitepaper 06.pdf.12.
[67] Brian Edwards., *Green Buildings Pay.* (Routledge London: E&FN Spon, 1998), 5.

enormous savings and productivity gains can be achieved through improved indoor air quality in the United States. He estimated $6 to $14 billion in savings from reduced respiratory disease, $1 to $4 billion from reduced allergies and asthma, $10 to $30 billion from reduced Sick Building Syndrome (SBS) related illnesses, and $20 to $60 billion from direct non-health related improvements in worker performance.[68]

Other studies done by the Heschong Mahone Group on the benefits of daylighting cite that student performance in day-lit schools indicate dramatic improvements in test scores and learning progress. One study showed that students in Orange County, California schools with more day-lighting in their classrooms improved their test scores 20 percent in math and 26 percent in reading compared to students in schools with the lowest levels of day-lighting. Also, a comparison of department stores with skylights versus those without showed 40% higher sales in stores with skylights.[69]

One way to approach resolving how to include health and productivity savings in green buildings was adopted by a recent report to California's Sustainability task force. In this report the authors recommend assigning a 1 percent productivity and health gain to buildings attaining a LEED Certified of Silver level, and a 1.5 percent gain for buildings achieving a Gold or Platinum level, as seen in Figure 8.3.[70]

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[68] Charles J.Kibert., *Sustainable Construction Green Building Design and Delivery.* (New Jersey: John Wiley & Sons, 2005), 385.
[69] Ibid, 386.
[70] Ibid., 387.

Human Performance Improvements Associated with Green Buildings

Green Building Attributes	Productivity Benefits
Increased tenant control over ventilation	0.5% to 34%
Increased tenant control over temperature and lighting	0.5% to 34%
Control over lighting	7.1%
Ventilation control	1.8%
Thermal control	1.2%

(Figure 8.3 Performance improvements in green buildings)

Savings are the equivalent of $600 to $700 per employee per year, or $3 per square foot for a one percent gain, and $1,000 per employee per year, or $4 to $5 per square foot for a 1.5 percent gain.

For owners the benefits are numerous with improved indoor environmental quality. This can mean higher property values, longer tenant occupancy and lease renewals, reduced insurance and operating costs, and good publicity. For tenants the benefits include reduced absenteeism, better employee morale, reduced liability risks and community recognition. The information as described portrays some of the positive aspects of green building design and the kind of results that can be achieved. The benefits are seen in building fixed costs, utilities, operations, and indirect soft costs like

human health, employee comfort and increased productivity. High performance buildings also benefit the environment and society in general. The ability to express and justify these benefits in an economic analysis will be a determining factor on whether or not to pursue the route of the high performance building as opposed to a more conventional design and construction.

Chapter 9

NORTHWEST GREEN BUILDING

As evidenced in the preceding chapters, green building is emerging and is changing the focus in the construction industry. The various aspects of green design carry with them changes for architects, owners, builders and industry professionals. But, it is not growing at the same pace everywhere. The question is," how is it developing in Washington State, specifically in Spokane and Coeur d'Alene. To develop a preliminary answer to this question, I developed a self selecting questionnaire to ascertain the outlook and experience of local architects and other industry professionals regarding the green building industry. (Appendix A) The interviews were conducted during the months of December 2006, and January 2007. The methodology was first to conduct local interviews with architectural firms to help formulate a follow-up on-line survey that would go out to various AIA chapters in Washington State that could be presented to chapter members to get a broader outlook at the green building industry. I consulted a professional associate to help devise questions that would cover a broad basis for gathering information on green building design and development. A qualitative approach was taken where phone interviews were conducted representing 18 different architectural firms in the Spokane and Coeur d'Alene area, both principals of small and medium sized firms and individual practitioners.

Objectives of the questionnaire included the following:

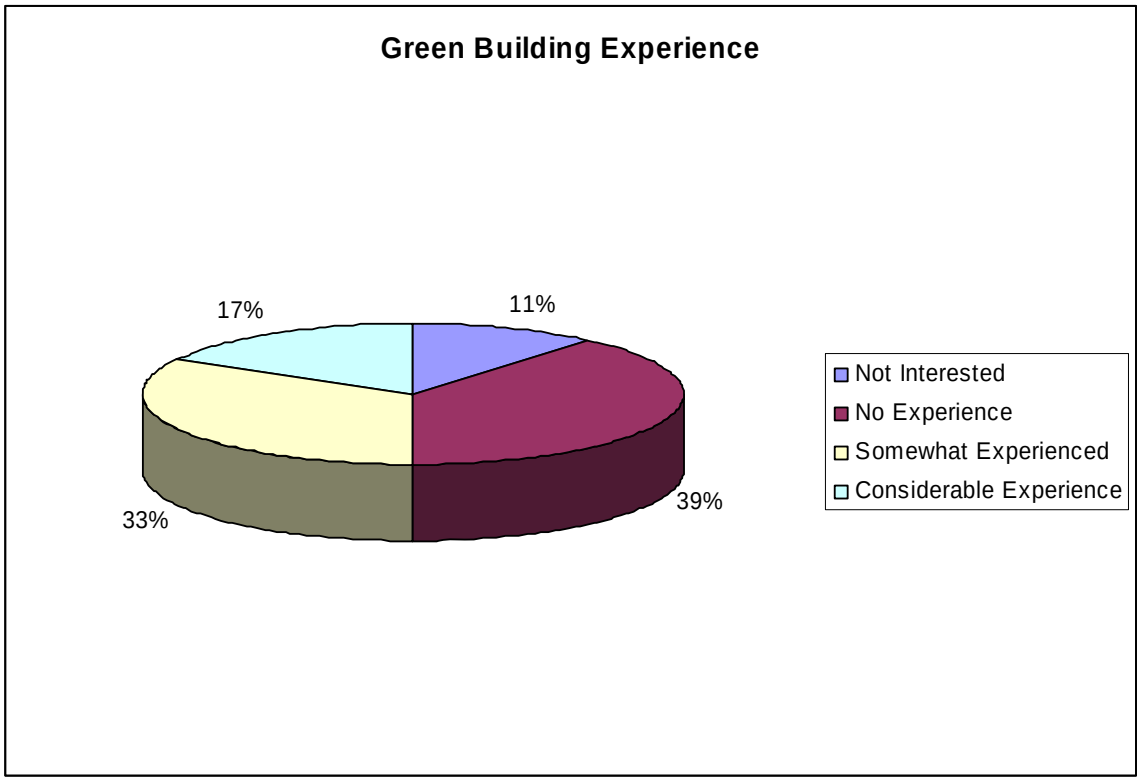
- To determine the level of experience in sustainable design
- To find out the attitude toward green building

- To examine what were the results of their experience
- To learn the reasons for lack of involvement in green building
- To determine the barriers that may exist to getting involved in green building
- To find out the extent of the market for green building in Spokane and Coeur d'Alene

With the firms that had experience, questions were asked on whether it was a positive or negative experience, and how was it different from conventional designed projects. Other areas of interest were finding out if the process of working with green design promoted more integration, and how it affected communication and teamwork. Did firms incorporate some green measures into design, or were they involved with a LEED certification project. In any case, I wanted to find out the estimated additional costs for adding green measures to a given project. Respondents were asked if there is necessarily a market for green building in the northwest, particularly in the Spokane/Coeur d'Alene area. The questionnaire also focused on whether or not they were marketing themselves as a green design firm or encouraging their staff to obtain specialization in this area.

Of firms without experience, the goal was to find out why they had not been involved and what the perceived barriers were to getting involved. Had the firm persuaded clients or any of the staff members in the company to attempt a green building project? If they decided to pursue green design more, would it be a marketable advantage for their company. Another focus was to find out if they saw themselves working with green design in the future; if no, why not? One last element was to get a better focus on their attitude, and that of their clients, toward green building.

The results were mixed. Asked what level of experience they had; 11% (2) were not interested, 39% (7) had no experience to date, 33% (6) had some experience with at least doing a partial green project, 17% (3) were in an advanced stage, having incorporated several green design features in projects and some LEED-accredited staff in the firm. (Figure 9.1)

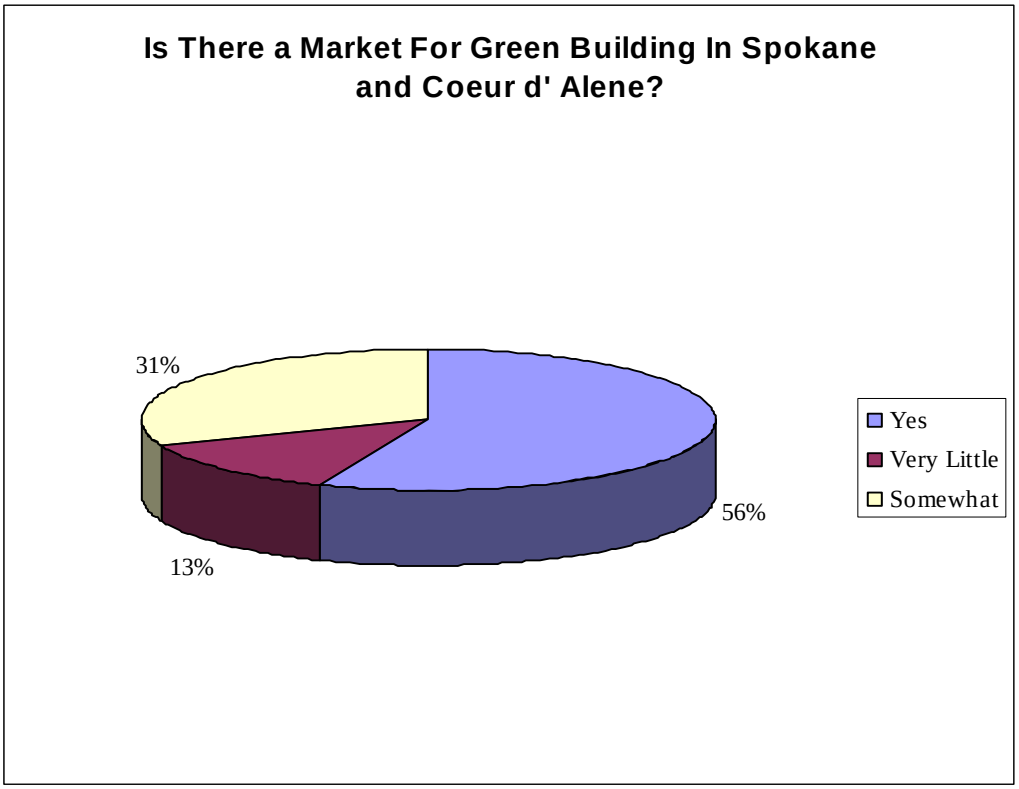


(Figure 9.1 Green building experience)

Of the 7 firms that had experience in green design, they said it was a positive experience for various reasons. Asked what caused the experience to be positive or negative, some responses including “doing the right thing and making a difference,” and “ knowing that you’re trying to do things better for the future and making things better for the present,” was why they felt it to be positive. Some respondents, however, cited that working with

green building, specifically a LEED project, would be cumbersome and require a lot of hoops to jump through.

Asked whether the process of green building improved communication and teamwork, 28% (2) said that it hadn't changed the process much, they were already fairly well integrated in their communication, 42% (3) said that it involved more coordination with clients' consultants and mechanical and electrical aspects of the project. The overall sense was that it required considerably more involvement, but it was necessary for project success. On whether or not there is a market for green building in the Spokane Coeur d'Alene area a surprising 56% (10) said yes, 13% (3) stated that there wasn't much activity right now, and 31% (6) said that the market is developing here but it is slow (Figure 9.2)



(Figure 9.2 Market for green building in Spokane and Coeur d'Alene)

There were varying reasons why firms were not involved with green building. One of the main concerns was cost, 66% (6) of respondents said that clients would not get involved because of the cost associated with green design. (Figure 9.3) Despite the concern over cost, when asked if a green project necessarily would cost more, 55% (5) said they weren't sure or that it wouldn't need to cost more. Several firms in Coeur d'Alene cited that the only current LEED project to date was the Post Falls City Hall. However, the city opted to not obtain LEED certification because of additional costs and documentation requirements. They are, however, proceeding with some green features in the project. Of the firms questioned, 33% (3) said there was a lack of client interest or education regarding green building which inhibited them from pursuing it any further.

Perceived Barriers To Green Building

Additional cost associated with products and systems	64% (5)
Willingness and interest of clients	33% (3)
Education and perception of clients on cost benefits	11% (1)
Limited on types of materials and cost of green products	22% (2)
Product and feature design can create problems	11% (1)
Payback on investment could be long	11% (1)

(Figure 9.3 Barriers to green building)

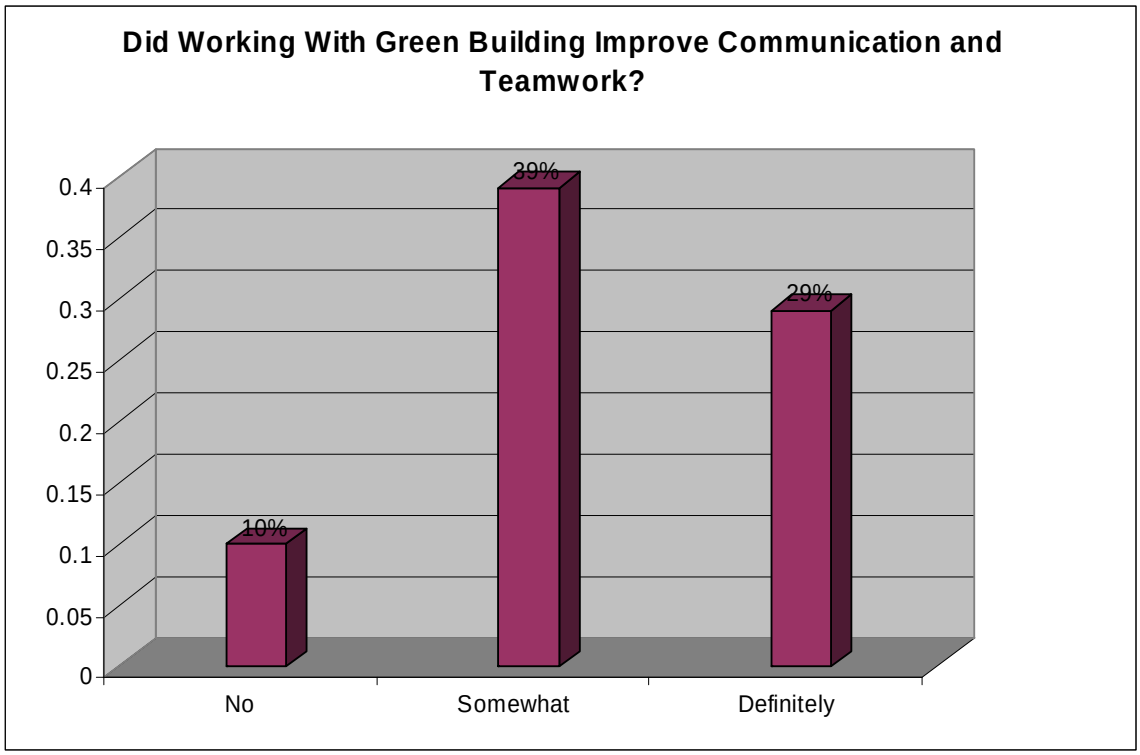
Statewide Survey

The interview was to be a precursor to the on-line survey in fine tuning what questions to ask for a mixed clientele. The objective of the survey was generally the same as the interview, but to reach a broader audience. The survey was sent to the different AIA chapters in Washington State and to 10 various owners, contractors and construction managers. (Appendix B) With an estimated audience of 200 to 300, I received a 5 to 10% response of 26. The survey was sent out during the months of March and April 2007. I wanted to find out the level of involvement in green building and how managing and working with green building differed from conventional construction. Questions were also asked on whether there is a market for green building in Washington State, and what the barriers are in getting involved.

The results again were mixed and interesting. The companies surveyed ranged from a sole proprietor to over 40 employees. The level of experience and involvement with green building projects varied. Some were involved with managing a project 18% (4), but the majority of respondents 41% (9) have worked with the design of a green building. Another 18% (4) had either worked with a LEED project, or built a green building, and 23% (5) either consulted on a green project or were an owner-builder.

Asked whether managing or building a green building was more difficult than a conventional construction project, 23% (5) said it wasn't, 64% (14) said it was, and 13% (3) said it added considerable time and study. One of the aspects of green building is how it effects communication and teamwork. The responses were, 10% (2) said it didn't have an effect on communication and teamwork, 39% (8) said it did somewhat, and 29%

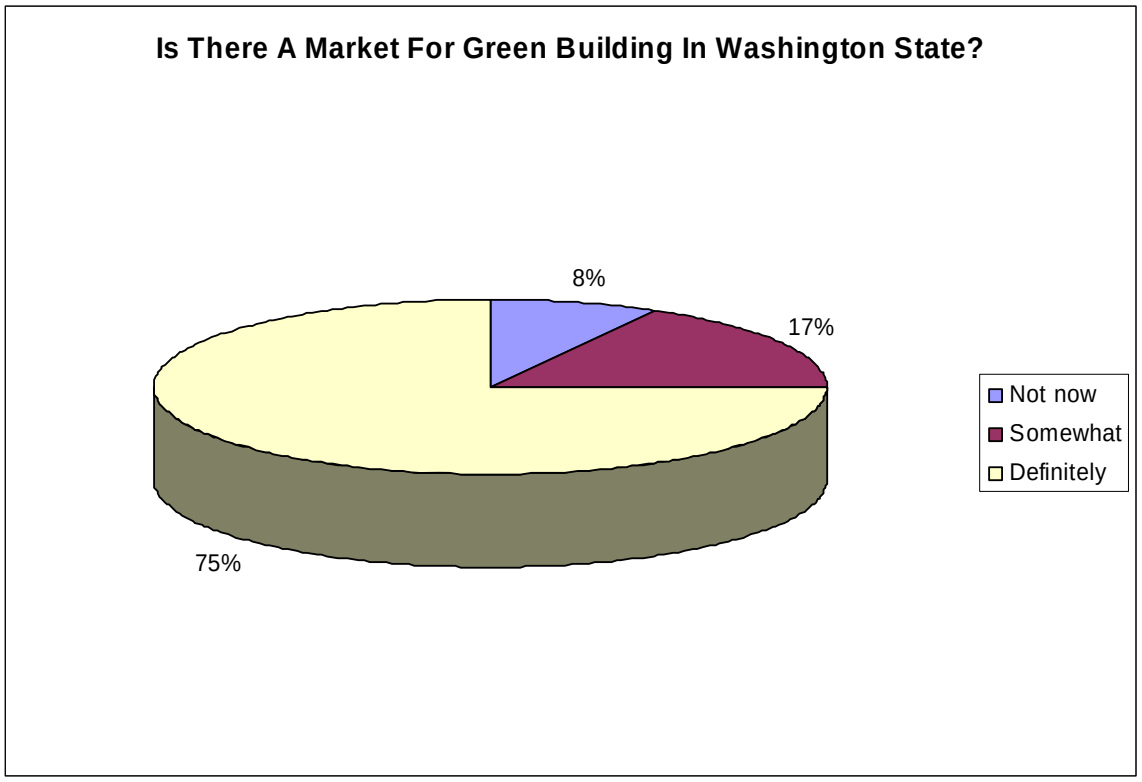
(6) said it definitely improved the process. Other respondents 24% (5) said they weren't sure or were still in the process. (Figure 9.4)



(Figure 9.4 Green building communication and teamwork)

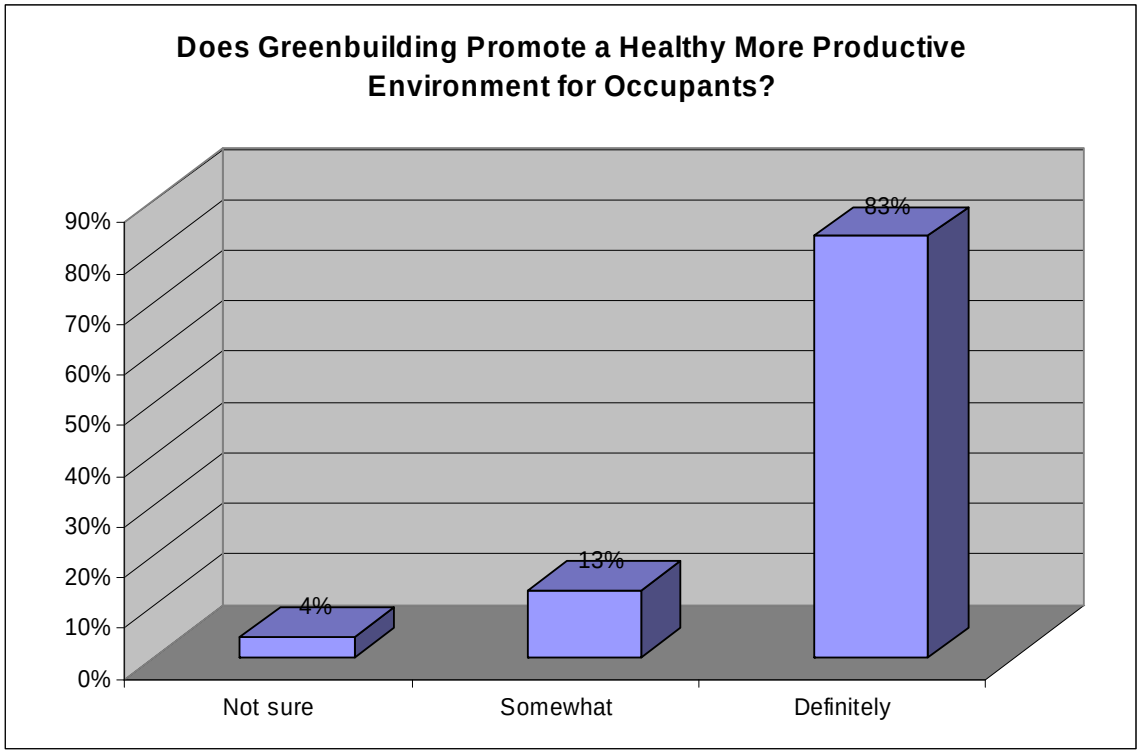
As discussed earlier, costs are a concern developing green buildings. The majority of respondents 57% (12) felt that the added cost to green projects was 0 to 5%, 29% (6) felt that is was 5 to10%, and 14% (3) thought it was10 to 20%. It was difficult to ascertain the energy savings for many who don't own and operate a building, because the majority of respondents didn't know what the savings was for a given project. Responses showed that 37% (8) said they didn't know, 14% (3) felt the savings was 0 to 5%, 18% (4) felt it was 5 to 10%, and 9% (2) felt the savings was more. The other respondents 23% (5) said they were still in design, or didn't know.

Regarding whether or not there is a market for green building in Washington State 8% (2) felt that there wasn't a market now but it will develop, 17% (4) felt there was somewhat of a market, and the majority of respondents 75% (18) said there was definitely a market in Washington. (Figure 9.5)



(Figure 9.5 Market for green building in Washington State)

Another goal of the survey was to find out if green buildings promote a healthy more productive environment for occupants. The results were, 4% (1) said they weren't sure, 13% (3) said there was somewhat of an effect, and an overwhelming majority of 83% (19) said green buildings definitely promote a healthy and more productive environment. (Figure 9.6)



(Figure 9.6 Green building health and productivity)

Many companies have encouraged staff members to obtain expertise in green building design, some were seeking to pursue specialization and others had already attained a level of expertise. Many respondents 23% (5) noted that they were not marketing themselves as specializing in green building, 5% (1) said possibly, 18% (4) said they were at the early stages, but 55% (12) said they were. Another concern of working with green design is whether or not green products are readily available and difficult to specify. Some respondents 9% (2) said it was more difficult to specify, 36% (8) said it was somewhat difficult, 41% (9) said it wasn't. The other 14% (3) said that there is a learning curve involved, specifying products in range for LEED credits would be difficult, and some products are readily available. There is a concern on whether the

products that are advertised as green really contain the accurate amount of recycled content or less toxic elements. Asked whether working with green design helped attract new clients 50% (11) said it didn't, 41% (9) said somewhat, and 9% (2) said it had increased a considerable amount.

Another focus of the survey was to ascertain what the difference was between working with green building as opposed to conventional construction projects. Some responses included; "it promotes collaboration and integration among team members, there was no difference, the challenges are unique, it adds to paper work requirements during design and construction, and there is more red tape in LEED certification." There was some concern that the selection of recycled content finish products and building materials, along with low VOC applications, greatly reduces interior and exterior look and feel. Others noted that the green process was more complex and required more effort, also inspections were more critical. Extra time and cost differences were also noted as some of the concerns and difference between the two.

I again wanted to find out the perceived barriers and reasons why there would be a lack of involvement in working with green design and construction. The majority of respondents cited that cost was a major barrier to achieving a green project. Other concerns include, extra paperwork especially with LEED projects, and time associated with the process. There is also a concern that some green design features such as natural light features, green wall coverings, HVAC systems that include ground loops, extra trees for shading, and green roofs all require extra maintenance and added costs to a project. Respondents also noted that the bureaucratic system and red tape associated with projects

slows down the process. The owners' willingness and interest is another reason why projects don't get off the ground. This can be attributed to the lack of knowledge and understanding in green building on the part of owners and contractors that inhibit projects to come to fruition.

The interview and survey responses portray a significant interest and growth in the northwest for green building. However, there are concerns as to the obstacles associated with its integration into the main stream of construction projects. Many companies have obtained a considerable level of expertise. Other companies said that they are marketing themselves as specializing in green building or foresee themselves as working in that direction in the future. Green building is a growing movement in the construction industry and one that appears to be gaining ground as more people become educated and aware of the potential benefits for owners and occupants.

Chapter 10

SUPPORT SYSTEMS

Sustainable building design has been advancing at a steady pace in the northwest and the United States, but more government incentives and support are necessary to further the efforts in the building industry. There are, however, new standards and mandates, such as the LEED rating system, and government requirements for sustainable building that encourage companies to better manage and understand the environmental impacts of their design considerations.

For the most part, sustainable design is a complex issue and there are organizations that can help designers and industry professionals in their pursuit of incorporating green building measures into their projects. The American Institute of Architects (AIA) "Environmental Resource Guide" offers detailed but constantly updated and authoritative information on the environmental impact of conventional building materials. The effects in terms of energy consumption, production, waste generation and indoor air quality are considered. It can act as a starting point for the consideration of consequences of design decisions.

The Canadian Mortgage and Home Corporation (CMHC) "Building Materials for the Environmentally Hypersensitive" contains hints for selection of materials, based on information gathered from residential demonstration products. It is broken down into categories describing different uses, considerations on installation and application, chemical composition and health risks.

The “Green Builders Sourcebook On-Line” is conceived as a support tool for Austin’s” Green Builder Program." It offers practical information on legislative issues, instructions for the use of different techniques and materials, and references to technical assistance services.

The “U.S. Green Building Council’s Sustainable Building Technical Manual” trains designers, builders, owners and operators of public and private facilities to implement green strategies. It offers step by step guidelines for energy and resource efficient building during pre-design, design, construction, operations and management. These and other resources are available to foster and support guidance and reflect different interpretations of sustainability in the building sector for industry professionals.[71]

In some cases guidelines, or checklists, just point out specific issues, such as recycling and re-use practices and the use of local materials. Other cases try to demonstrate the effort to set up more specific tools considering all implications of development, using an “integrated approach” to building design.

Sustainable building guidelines are also provided on-line by the “Austin City Connection” to promote an integrated approach to building design, operation, and management of municipal buildings. There are three different sections that pertain to building design, specifying for sustainability and operation and maintenance for city facilities.

The high performance building movement in residential construction has also been spurred along by local and national energy efficiency home building initiatives. These programs address building to higher energy codes and green standards. Consider the New York Green Building Initiative sponsored by the New York Department of

[71] Nicola Maiellaro, *Towards Sustainable Building* (Dordrecht Netherlands: 2001), 173-174.

Environmental Conservation (DEC). New York is among one of the first states in the nation to offer a tax incentive program for developers and builders of environmentally friendly buildings. The result of this has been the development of new technologies, and clean healthy places to live and work. Governor George Pataki, with strong support of the real estate, environmental, business and labor communities, has signed into law measures intended to encourage building owners to design, construct and operate buildings that are more in harmony with the environment.[72] DEC is currently updating the regulations that govern New York State's Green Building Tax Credit program. The New York State Energy Research and Development Authority (NYSERDA) provides technical assistance to DEC, and provides technical and financial assistance to those interested in building "green."

At the national level, the Environmental Protection Agency (EPA) launched its Energy Star Homes program that inspired builders to meet a higher standard of building performance with such features as reduced air infiltration, low e- glass, duct sealing and performance testing. Local government officials are also getting involved by encouraging sustainable practices in their building codes.

There are also more resources for builders interested in sustainable home building from local home builders associations such as the City of Seattle Sea Green Program, and the Master Builders Association of Snohomish and King Counties "Built Green Program." These programs provide various parameters and guidelines for what the organizations believe constitute sustainability in single and multifamily building projects. They were formed to create market distinctions for certain builders that wanted to

[72] New York State Green Building Initiative-Why Green Buildings? New York State Department of Environmental Conservation. 2005. http://www.dec.state.ny.us/website/ppu/grnbldg/index.html.

incorporate green features into their home design. Some areas include site selection and water conservation that saves energy and eliminates water pollutants. Others include heating and cooling strategies, lighting efficiency, health and indoor air quality, moisture control and efficient HVAC systems, and materials efficiency including reduce and reuse strategies. Still other elements include recycling job waste, using recycled content products, promoting environmentally friendly operations and maintenance which will address education issues for the occupants.[73]

Locally, the Avista Utility Corporation offers incentives for developers of new residential construction and owners of existing homes to incorporate new energy efficient measures into their homes. This can be a $200 rebate for installing a more energy efficient gas furnace or boiler system, a $25 incentive for a more efficient electric or gas water heater, or a tankless water heater. There is also a 70 cent per square foot incentive for more efficient energy star windows. On existing homes, there is a 14 cent per square foot incentive when adding higher levels of insulation in the attic floors and walls when they are below certain levels.

In Avista's commercial division there are several incentives for energy conservation and adopting green options for buildings. In retrofit projects there are financial incentives for installing more efficient lighting, upgrading building shell measures beyond the local code like insulation and windows, and adopting new heating, ventilating and air conditioning (HVAC) systems and controls. In new construction, where owners want to qualify for A LEED certification, there are incentives for every green measure installed, such as improved HVAC systems, lighting, and water conservation systems,

[73] Green Built Imagine If Everyone Did. Master Builders Association of King and Snohomish Counties. 2003. http://www.builtgreen.net/.

etc. After a building has been certified, Avista gives a rebate for a set dollar amount per square foot of building space. There are more projects being developed in different sectors like education, institutions and government.

There is also growing support from the insurance industry for green technology. Insurers are showing new strategic directions as they focus on reducing the risks associated with climate change in hopes of minimizing the occurrence of natural disasters such as fires, floods and hurricanes. By reducing harmful greenhouse emissions, which in turn should minimize global warming, insurers are hoping to reduce losses. The green building arena and its participants, such as environmentally friendly fire resistant building materials manufacturer Barrier Technology Inc., are looking to benefit from the additional support from this sector.

One area in particular that will benefit from this support in the insurance arena is the green-building sector. Green building techniques in the industry propose significant steps in reducing the harmful impacts to the environment caused by traditional energy generation and building operations. Insurance providers are beginning to reward businesses that incorporate these techniques. For example, Fireman's Fund insurance recently announced new coverage that will promote green building with the introduction of Certified Green Building Replacement and Green Upgrade Products. It will enable commercial property owners to rebuild and replace using green alternative materials and products. Working closely with the U.S. Green Building Council's LEED program and

the Green Building Initiative's Green Globe Program, Fireman's Fund Insurance hopes to align their coverage with these major certification programs.[74]

[74] Van Zant, Dawn. "Green Building Support From the Insurance Industry Aims to Reduce Environmental Risks From Global Warming." Buildiners.Com Oct. 2006: 1-3. http://www.marketwire.com/mw/release_html_b1?release_id=176050.

Chapter 11

BUILDING ENERGY SYSTEMS

A major challenge for designers of high performance green buildings is to create a low energy profile. The demand for energy will continue to grow because of our emerging world population, but finite resources, such as petroleum production, will begin to peak. Considerable energy and resources will be necessary in order to extract remaining oil resources, while economies around the world will still depend on abundant cheap energy, none more so than the United States. The mass consumption of energy in today's construction industry can be offset with dramatic energy reductions, accompanied by great progress in passive design. It will be needed to meet the future demands of the built environment. As we approach the awareness that energy costs are likely to escalate substantially because of fierce international demand and competition, there is still time to make important decisions with respect to the type of buildings we create.

The green building movement is attempting to improve energy performance and influence a major shift in how buildings are designed. Advocates of this change believe that buildings should be neutral or net exporters of energy. Advancing the use of solar and other innovative energy systems may enable buildings to generate at least as much energy as they consume. Energy consumption remains the single most important green building issue because of its environmental impacts and the probability of higher future energy costs. In today's green building environment, there is a way to offset this demand through efficient building shell design and HVAC systems that help reduce the demand for expensive and environmentally damaging sources of fossil fuel energy.

Passive Design

One of the starting points of green design must be a full consideration of passive solar design, or passive design. Passive design includes the design of the buildings' heating, cooling, lighting and ventilation systems relying on sunlight, wind, vegetation and other naturally occurring resources. This is the consideration of all possible measures that will reduce energy consumption before the consideration of active and powered systems such as chillers, boilers, pumps and other powered equipment.

Passive solar building design is an essential element in green building. That is an approach that locates the long side of a building on its site with a true east-west axis minimizing solar loads on the east and west surfaces during the summer. South facing walls receive a variable solar gain during the day, and windows are easily protected from the solar gains during the summer through the use of overhangs, shading devices or recessing the windows. Thermal mass is an important aspect of passive design. To provide heating the design of the building should allow materials with high heat capacity and mass to store energy during the day. Materials such as brick, concrete, and adobe used for floors and walls can absorb energy during the day and release it at night. In hotter climates like Florida, buildings should have minimal mass that is lightweight and well insulated. Solar energy is renewable but not totally dependable. A home or business must have a back-up energy source when the sun does not shine.

Solar Hot Water

Solar energy is used for heating water, to produce electricity to power our homes, and can provide some electrical demands for commercial buildings. Hot water systems are more prevalent in residential homes as some local utilities offer incentive programs to install these energy saving systems that preheat domestic hot water. The basic technology is simple. Sunlight strikes and heats an "absorber" surface within a "solar collector." Either a heat transfer fluid or the actual potable water to be used flows through tubes attached to the absorber. The heated water is stored in a separate preheat tank until needed. If additional heat is needed, it is provided by electricity or fossil fuel energy provided by a conventional heating system. By reducing the amount of heat provided by the conventional water heating system, solar water heating systems directly substitute renewable energy for conventional energy, reducing the need for electricity and fossil fuels.

Geothermal

Geothermal systems (ground source heat pump systems) are similar to ordinary heat pumps and air conditioners but utilize the ground instead of outside air for heating and cooling, and in other cases for hot water.[75] They extract heat energy during the winter and act as a heat sink in the summer. The ground is a viable alternative to air because of its relatively stable temperature. In many locations the soil temperature does not vary much over the annual cycle below a depth of 6.5 feet. For example, in Louisiana outdoor temperatures can range from winter lows of 32 F to summer highs of 95 degrees F, while

[75] Mark Wasserman, "Designing Sustainable green Buildings" (New York Institute of Technology, 1995), 58.

the soil temperature is never greater than 65 F and never falls below 64 degrees F, averaging around 68 degrees F. Different systems have been developed to thermally connect the heat pump to the ground, but the two most prevalent ones are vertical and horizontal systems.

Horizontal systems use plastic piping placed in trenches to exchange heat with the ground. The advantage of this type is that it is lower cost because of fewer requirements for special skills and equipment, and less uncertainty of subsurface conditions. The disadvantages of this type of system are its high land use requirements and wider temperature swings of the soil at lesser depths.

Vertical ground piping is the most common type of system used in commercial applications. Vertical tubes are placed in bore holes and manifolds at the surface. The advantages of this system are low land area requirements, stable deep soil temperatures with greater potential for heat exchange with groundwater, and adaptability to most sites. The disadvantages are potentially higher costs, problems in some geological formations and the need for experienced drillers. This new development on heat pump technology helps make geothermal heat pumps among the most efficient and comfortable forms of heating and cooling today. Geothermal systems are being specified in residential and commercial buildings as environmentally friendly technology.

Photovoltaic Systems

Photovoltaic (PV) cells are semiconductor devices that convert sunlight into electricity by the use of solar cells. Photovoltaics are almost maintenance free and seem to have a long life span. They have no moving parts, and energy storage, if needed, is

provided with batteries. They are starting to be used more in homes and commercial buildings to offset electrical demands. They are also being used in large solar farms on the west coast where large fields of mirrors harvest the sun and turn it into electricity. Countries like Japan are investing heavily into photovoltaic, believing that this renewable energy source is the fuel for the future. In Tempe, Arizona researchers using an unusual solar cell have set a new efficiency record for capturing power from the sun. They have hopes of manufacturing it cheaply, because it can be produced in the same factories that make computer chips.[76] The cell and related systems capture and convert more than 20 percent of the sunlight to electricity. Commercially available systems are generally only 10 to 12 percent efficient.

Especially interesting are building-integrated photovoltaic (BIPV) systems that integrate PV directly into building materials, such as semitransparent insulated glass windows, skylights, roofing shingles and raised seam metal roofing. They can be integrated into roofs and facades as part of the outer building cladding. PV systems are modular; they can be added to, removed and reused in other applications. Depending on the type of collection medium, BIPV can generate approximately 5 to 10 watts of power per square foot of collector area in full sunlight. That means a collector area of 100 to 200 square feet is needed per kilowatt of capacity. This will vary with latitude and climate and orientation of the building, but annual energy output ranges from 1,400 to 2,000 kilowatt-hours per kilowatt of installed system capacity.[77]

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[76] Mark Wasserman, "Designing Sustainable Green Buildings" (New York Institute of Technology, 1995),62.

[77] Charles J. Kibert, *Sustainable Construction Green Building Design and Delivery* (New Jersey: John Wiley & Sons, 2005), 225.

Wind Energy

The wind is an abundant source of energy that has been harnessed since ancient times. After many years of stagnation in the field of alternative energy sources, the windmill is making a comeback. It is the fastest growing form of energy production with an estimated year-to-year growth of 25 %. Systems have been designed for small residential applications to large wind farms located in Oregon and California. The U.S. Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) approximates that the cost of wind energy has declined from $0.40 per kilowatt-hour in the 1980's to less than $0.05 per kWh today and will continue to decline. The American Wind Energy Association (AWEA) has estimated that, with the support of governmental bodies and utilities, wind energy could provide at least 6 percent of the nation's electricity supply by 2020.[78]

Wind turbines produce no pollution, and using wind power will offset pollution that would have been generated by utility companies. Over its life, a small residential wind turbine can offset approximately 1.2 tons of air pollutants and 200 tons of greenhouse gases (carbon dioxide and other gases which cause climate change).[79] A wind turbine is designed to operate under varying conditions according to its "cut in" and "cut out" speeds. Cut in speed is the minimum speed at which a turbine needs to move to produce electricity. Cut out speed is the maximum speed above which no power production is expected. The turbine's rotor blades must spin at a steady speed in order to tie into a

[78] Charles J. Kibert, *Sustainable Construction Green Building Design and Delivery* (New Jersey: John Wiley & Sons, 2005), 226.
[79] What Do I Need To Know To Purchase A Residential Wind Turbine? American Wind Energy Association. http://www.awea.org/faq/rsdntqa.html.

utility's power grid. On a larger scale wind farms are coming on line that will provide a balance of green energy to homes and office buildings.

The AWEA's third quarter 2006 report states that the industry was on track to install a record 2,750 megawatts (MW) of generating capacity in 2006. In other record breaking news, one of the projects completed in the last quarter of 2006 was the FPL Energy's 735- MW Horse Hollow Wind Energy Center in Texas. It has shattered all previous records for the country's and the world's largest wind farm. One megawatt of wind power produces enough electricity on a typical day to power the equivalent of 250-300 homes.[80]

The U.S. wind energy industry is working hard to meet current demands for new wind farms, but the nation needs a long-term extension of the wind energy production tax credit for companies to plan beyond 2007. Wind farms produce tremendous savings, estimated at a half billion cubic feet of natural gas per day, and help reduce the pressure that is driving up natural gas imports. Wind energy may help stabilize electricity costs and strengthen our energy security.

Fuel Cells

Fuel cells are devices that generate electricity in a process that is described as reverse electrolysis. In electrolysis, electricity is input to electrodes to decompose water into hydrogen and oxygen. In a fuel cell, hydrogen and oxygen molecules are brought back together to generate electricity, water and heat. In principle a fuel cell operates like a

[80] Belyen, Kathy. "AWEA Third Quarter Market Report: U S Wind Energy Industry Completes World's Largest Wind Farm, Expects To Add over 2,700 Megawatts in 2006." American Wind Energy Association, News Room Oct. 2006: 1-2. http://www.awea.org/newsroom/releases/AWEA_third_quarter_market_report_102406.html.

battery, but unlike a battery, it does not run down or require recharging. A fuel cell takes in hydrogen, but any hydrogen rich fuel can be processed to extract its hydrogen for fuel cell use. Current generation fuel cells last anywhere from one to six years before they wear out or need an overhaul. The principle concept was discovered in 1839, but it took almost 130 years for the technology to come to the forefront, first in the U.S. space program and more recently in new technologies such as power generation for commercial buildings.[81] Right now all the major auto makers are working to commercialize a fuel cell car.

Although fuel cells are still expensive to manufacture, they will depend on ongoing innovations to ensure that they will become more cost effective. They are beginning to make more economic sense for buildings and utilities. The potential for home and commercial building power systems to use fuel cells can be high. Another consideration is that the heat generated by some types of fuel cells can be used for thermal cogeneration in building power systems. As a power generator for residential homes they can be connected to the electric grid to provide supplemental power, or installed as a grid-independent generator for on-site service in areas that are inaccessible by power lines. They operate silently, reduce noise pollution, as well as air pollution, and the waste heat from a fuel cell can be used to provide hot water or space heating for a home. Many of the prototypes being tested for residential use extract hydrogen from propane or natural gas.[82]

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[81] Charles J. Kibert., *Sustainable Construction Green Building Design and Delivery.* (New Jersey: John Wiley & Sons, 2005), 228.

[82] Fuel Cell Basics: Application. Fuel Cell 2000, The Online Fuel Cell Information Resource. http://www.fuelcells.org/info/fclib.html.

Government can provide a positive momentum on the development of fuel cell technology. The U.S. government has taken bold steps in funding research and development of fuel cells. In 2002 the Department of Energy (DOE) formed the Solid State Energy Conservation Alliance made up of commercial developers, universities, national laboratories and government agencies to develop low-cost, high-density fuel cells for a broad range of applications. The DOE has also funded $100 million to fund 25 hydrogen research and development projects that can help change the way we power our nation. These projects support the President's Advanced Energy Initiative which seeks to reduce our dependence on foreign sources of energy. An integral part of this is the Hydrogen Fuel Initiative (HFI) which seeks to make hydrogen fuel practical and cost effective. As a result, the 2007 budget has been increased and the cost of hydrogen fuel cell has been cut by more than 50 percent in four years.[83] Fuel cells provide an emerging green technology that can make good environmental and economic sense. Utilizing alternative sources of energy helps promote a better balanced approach to sustaining our economy because of less dependence on and use of foreign oil and diminishing fossil fuel reserves.

The various sorts of alternative energy strategies are elements that can be utilized in buildings. The green building movement fosters this type of change and encourages owners and designers to seek different technologies in new building development.

[83] Stevens, Craig. "US Department of Energy Awards $100 million in Fuel Cell R&D." Greenbuild.com Nov. 6, 2006: 1-3.http://www.igreenbuild.com/_coreModules/contactDisplay.aspx?contactID=2657.

Chapter 12

CONCLUSION

Sustainable development involves an effort and mindset in utilizing best practices to ensure that our valuable resources are used in the most efficient way possible, that waste is minimized, and that we sustain our human and natural environments now and for future generations. One predominant area to incorporate these principles is in building resource efficient buildings, or green buildings. In this thesis I presented the nature of green building and its role in the construction business. I wanted to show how it is affecting the way buildings are being constructed, that it is making a difference in our internal and external environment, and provide practical methods of achieving the goal of energy efficient and healthy buildings for occupants. I wanted to determine the level of involvement in green building in the local building community and throughout Washington State.

There are many elements involved in the process of developing and constructing a green building. The process involves effective site and building design, construction, materials, indoor air quality, systems and operation. It initially starts with the vision of the owner insisting on taking the path in a building project to pursue green building design.

Working closely with the architect and other building professionals, the owner is involved in an educational process of learning about the products and design options that go into a project. Design includes the assessment of the materials and products to be used from acquiring raw materials, manufacturing, implementation, operation and

ultimate disposal or reuse of materials. Finding architects who are knowledgeable about sustainable design is crucial; they are the integral link to formulating the green building design. The builder is also a critical factor in the education and planning process of green building. The design and development process requires an integrated approach where all parties work closely together to achieve the vision and goals of the project. In this way the education level is increased and there is a general consensus on what is involved and what is expected for project success.

Once the green building design has been established, the material and system selection is critical in making sure the design meets energy conservation goals, an improved indoor environmental quality, and that systems operate effectively. New low toxic and recycled content products are more readily available today for the designer, and the market continues to expand. The nature of green building provides an economic cost benefit for owners of residential and commercial buildings in reduced energy bills for operation, and increased property value. It also provides benefits in increased productivity in the workplace, and minimizes health problems due to the sick building syndrome.

Green building is an emerging force in the building industry today. Just how much depends on the support and willingness of owners, government bodies and organizations that are promoting its development. The interview and survey I did shows that there is initial movement in the Spokane/Coeur d'Alene area and in Washington State for green building. It is not an overall consensus, but one that is growing with strong interest in the professional building community.

The principles of sustainable building are important in our expanding world where our resources are being consumed at a rapid pace, energy consumption is high, and the need for conservation is crucial. Constructing buildings that are more efficient will help alleviate the increasing demand for energy, especially from fossil fuel electric power generation. Improving the indoor environmental quality in buildings will help promote a healthier more productive atmosphere where we live and work. There are many industries that can incorporate sustainable principles. The building industry represents a major area where utilizing green building design can help to alleviate the construction industry's harmful effects to our environment and improve the lives of people.

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APPENDIX A

Green building phone interview questions

GREEN BUILDING QUESTIONS - FIRMS WITH EXPERIENCE

Firm:_____ Contact:_____

Location:_____ Phone:_____

Type of projects:_____

Do you have experience working with green building design?

If so, was it a positive or negative experience or a combination of both?

How did working with green building design compare to conventional designed projects?

Did working with green building promote a more integrated design process, and how did it affect teamwork.

Have you done a LEED rated project, if so, what was the approximate additional percentage cost added to the project?

If not doing a LEED project, did you use some green concepts, if so, what was the approximate additional cost of one of your projects?

Do you have any information about the estimated payback of one of your green designed projects?

Is there a market for green building in the northwest particularly in the Spokane Coeur d'Alene area?

Does green building promote a healthier more productive environment for occupants?

Is green building good for the environment, how so?

Has the firm encouraged staff members to obtain expertise in sustainable design, and will you recruit new employees with LEED experience?

Have you created new marketing material for green building?

Do you have trouble specifying and obtaining green products? If yes why, if no why not?

What are the attitudes of the clients toward green building design?

GREEN BUILDING QUESTIONS - FIRMS WITHOUT EXPEREIENCE

Firm:_____ Contact:_____

Location:_____ Phone:_____

Type of Projects:_____

If not working with green building design, what were the reasons for the lack of involvement?

What are the perceived barriers to getting involved in green building?

Does green design necessarily have to cost more than conventional designed projects?

Is green building good for the environment, how so?

Have you tried to persuade clients or others in your firm to attempt a green building project?

Is there a market for green building in the northwest particularly in the Spokane Coeur d'Alene area?

Could working with green building design be a marketable advantage for your company, and potentially draw in new clients?

Is it difficult to specify and obtain green products? If yes why, if no why not?

Do you foresee yourself working with green building design in the near future, why or why not?

What are the attitudes of your clients toward green building design?

APPENDIX B
Statewide Web Survey Results

Question	Response Percent	Response Total
1. Do you have experience in green building?		
No	8.3%	2
Just looking into green building	4.2%	1
Somewhat experienced	66.7%	16
Very experienced	16.7%	4
Other	4.2%	1
8 years building our own sustainable house		
2. How large is your company?		
Sole proprietor	4.3%	1
1-10 employees	17.4%	4
10-20 employees	13.0%	3
20-30 employees	17.4%	4
30-40 employees	17.4%	4
More	30.4%	7
3. If experienced in green building what was the level of involvement?		
Consulted on projects	4.5%	1
Managed a project	18.2%	4
Designed a project with green measures	40.9%	9
Worked with LEED certification	9.1%	2
Built a green building	9.1%	2
Other	18.2%	4
Owner's agent on the design of multiple LEED certified buildings		
Owner-builder		
Worked with design that complied with some LEED standards		
On site PM for convention center that attained LEED certification		
4. Was managing or building a green building more difficult than a conventional construction project?		
No	22.7%	5
Yes	63.6%	14

Added considerable time	9.1%	2
Other	4.5%	1

Recent experience with both LEED silver and certified projects

5. What are the perceived barriers to working with green buildings?

More cost, more effort.
Mostly tied to LEED paperwork.
Time especially in the initial design phases, money-both in time and construction.
costs working with materials and processes that are unfamiliar..
Tight budget resistance from engineers and community culture.
Building officials in some districts.
Lack of return on investment.
Client willingness, contractor participation and understanding material availability

6. If working with green building, did it improve communication and teamwork?

No	9.5%	2
Somewhat	38.1%	8
Definitely	28.6%	6
Other	23.8%	5

Not sure
No difference
Still in the process of first project

7. What was the approximate cost in percentage of doing a green project?

0%-5%	57.1%	l2
5%-10%	28.6%	6
10%-20%	14.3%	3

8. What was the initial energy savings of one of your green building projects?

Don’t know	36.4%	8
0%-5%	13.6%	3
5%-10%	18.2%	4
More	9.1%	2
Other	22.7%	5

30% projected
Don’t know yet
Still n the design phase

9. Is there a market for green building in Washington State?

Not sure but will grow	8.3%	2
Somewhat	16.7%	4
Definitely	75.0%	18

10. Does green building promote a healthy more productive environment for occupants?

Not sure	4.3%	1
Somewhat	13.0%	3
Yes definitely	82.6%	19

11. Have you encouraged staff members to obtain expertise in green building design?

Maybe in the near future	13.6%	3
Yes	72.7%	16
Already have specialization	13.6%	3

12. Are you marketing your company as specializing in green building?

No	22.7%	5
Possibly	4.5%	1
At the early stages	18.2%	4
Yes	54.5%	12

13. Do you have trouble specifying green products?

Yes	9.1%	2
Somewhat difficult	36.4%	8
No	40.9%	9
Other	13.6%	3

There is a learning curve involved.
Finding local products within range for LEED projects would be difficult.
Generally overseeing architect, seems products are readily available.

14. Has working with sustainable design helped attract new clients and projects?

No	50%	11
Somewhat	40.9%	9
Considerable amount	9.1%	2

15. If yes, how much has business improved?

Very little	57.1%	8
Moderate amounts of business	42.9%	6

16. How did working with a green building project compare to conventional construction projects?

I was a PM on the one LEED project we had, it was a lot of "extra" paperwork.
It promotes collaboration among team members, it encourages people to learn and search for answers.
No difference, difference would be seen on follow through on LEED certification.
The challenges are unique but not insurmountable.
More red tape in LEED certification
Caused much more integration among all design disciplines involved.

17. What are the attitudes of your clients toward green building?

They sometimes see it as another expense and additional effort on their part.
I am the client, we very much wanted a green convention center to tout as a marketing tool and to be good stewards of the environment.
It's fine as long as it doesn't cost more or take longer.
Mixed-most don't know what it means to their project.
Most are positive.
More clients are either mandating green building concepts i.e. governmental agencies, or want to look at the impacts to project feasibility.
It varies, some see it as mandatory, others still view it as a luxury.

18. If no experience in green building what is the reason for lack of involvement?

Owner and contractor set in building material specifications as it relates to the overall cost and past experience.
Have not had a client that was interested in green building.
Age, I plan to retire soon.
We are providing engineering/architectural services for a Department of Energy nuclear waste treatment project and green building design is not included in the basis of design.
Lack of interest.

19. What are the perceived barriers to working with green building?

Higher first costs.
Cost, availability, benefits realized relative to scale.
Additional construction costs, paper work costs, and cost of LEED submittal.
Red tape and regulating system.
Probable the relative short operating life of these facilities doesn't warrant consideration of green building by the DOE.

20. have you tried to persuade client or others in your company to attempt a green project?

No	22.2%	2
Attempted with no results	22.2%	2
Clients are not interested	22.2%	2
Other	33.3%	3
Yes.		

21. Could working with green building potentially draw in new clients and business?

Possibly	50%	5
Yes	50%	5

22. Is it difficult to specify green building products?

No	40%	4
Somewhat	40%	4
Yes	10%	1
Other	10%	1
Requires additional specifications		

23. Do you foresee yourself working with green building in the future?

If the market changes	20%	2
Possibly	20%	2
Yes	60%	6