Green Building, also known as **green construction** or **sustainable building**, is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle: from siting to design, construction, operation, maintenance, renovation, and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. [1]

Although new technologies are constantly being developed to complement current practices in creating greener structures, the common objective is that green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment by:

- Efficiently using energy, water, and other resources
- Protecting occupant health and improving employee productivity
- Reducing waste, pollution and environmental degradation [1]

A similar concept is natural building, which is usually on a smaller scale and tends to focus on the use of natural materials that are available locally. [2] Other related topics include sustainable design and green architecture.

Contents

// Reducing environmental impact

Green building practices aim to reduce the environmental impact of buildings. Buildings account for a large amount of land use, energy and water consumption, and air and atmosphere alteration. Considering the statistics, reducing the amount of natural resources buildings consume and the amount of pollution given off is seen as crucial for future sustainability, according to EPA.The environmental impact of buildings is often underestimated, while the perceived costs of green buildings are overestimated. A recent survey by the World Business Council for Sustainable Development finds that green costs are overestimated by 300 percent, as key players in real estate and construction estimate the additional cost at 17 percent above conventional construction, more than triple the true average cost difference of about 5 percent.

Goals of green building

The concept of sustainable development can be traced to the energy (especially fossil oil) crisis and the environment pollution concern in the 1970s. [3] The green building movement in the U.S. originated from the need and desire for more energy efficient and environmentally friendly construction practices. There are a number of motives to building green, including environmental, economic, and social benefits. However, modern sustainability initiatives call for an integrated and synergistic design to both new construction and in the retrofitting of an existing structure. Also known as sustainable design, this approach integrates the building life-cycle with each green practice employed with a design-purpose to create a synergy amongst the practices used.

Green building brings together a vast array of practices and techniques to reduce and ultimately eliminate the impacts of buildings on the environment and human health. It often emphasizes taking advantage of renewable resources, e.g., using sunlight through passive solar, active solar, and photovoltaic techniques and using plants and trees through green roofs, rain gardens, and for reduction of rainwater run-off. Many other techniques, such as using packed gravel or permeable concrete instead of conventional concrete or asphalt to enhance replenishment of ground water, are used as well.

While the practices, or technologies, employed in green building are constantly evolving and may differ from region to region, there are fundamental principles that persist from which the method is derived: Siting and Structure Design Efficiency, Energy Efficiency, Water Efficiency, Materials Efficiency, Indoor Environmental Quality Enhancement, Operations and Maintenance Optimization, and Waste and Toxics Reduction. [4] [5] The essence of green building is an optimization of one or more of these principles. Also, with the proper synergistic design, individual green building technologies may work together to produce a greater cumulative effect.

On the aesthetic side of green architecture or sustainable design is the philosophy of designing a building that is in harmony with the natural features and resources surrounding the site. There are several key steps in designing sustainable buildings: specify 'green' building materials from local sources, reduce loads, optimize systems, and generate on-site renewable energy.

Siting and structure design efficiency

The foundation of any construction project is rooted in the concept and design stages. The concept stage, in fact, is one of the major steps in a project life cycle, as it has the largest impact on cost and performance. [6] In designing environmentally optimal buildings, the objective function aims at minimizing the total environmental impact associated with all life-cycle stages of the building project. However, building as a process is not as streamlined as an industrial process, and varies from one building to the other, never repeating itself identically. In addition, buildings are much more complex products, composed of a multitude of materials and components each constituting various design variables to be decided at the design stage. A variation of every design variable may affect the environment during all the building's relevant life-cycle stages. [7]

Energy efficiency

Green buildings often include measures to reduce energy use. To increase the efficiency of the building envelope, (the barrier between conditioned and unconditioned space), they may use high-efficiency windows and insulation in walls, ceilings, and floors. Another strategy, passive solar building design, is often implemented in low-energy homes. Designers orient windows and walls and place awnings, porches, and trees [8] to shade windows and roofs during the summer while maximizing solar gain in the winter. In addition, effective window placement (daylighting) can provide more natural light and lessen the need for electric lighting during the day. Solar water heating further reduces energy loads.

Onsite generation of renewable energy through solar power, wind power, hydro power, or biomass can significantly reduce the environmental impact of the building. Power generation is generally the most expensive feature to add to a building.

Water efficiency

See also: Water Conservation

Reducing water consumption and protecting water quality are key objectives in sustainable building. One critical issue of water consumption is that in many areas of the country, the demands on the supplying aquifer exceed its ability to replenish itself. To the maximum extent feasible, facilities should increase their dependence on water that is collected, used, purified, and reused on-site. The protection and conservation of water throughout the life of a building may be accomplished by designing for dual plumbing that recycles water in toilet flushing. Waste-water may be minimized by utilizing water conserving fixtures such as ultra-low flush toilets and low-flow shower heads. Bidets help eliminate the use of toilet paper, reducing sewer traffic and increasing possibilities of re-using water on-site. Point of use water treatment and heating improves both water quality and energy efficiency while reducing the amount of water in circulation. The use of non-sewage and greywater for on-site use such as site-irrigation will minimize demands on the local aquifer. [9]

Materials efficiency

Building materials typically considered to be 'green' include rapidly renewable plant materials like bamboo (because bamboo grows quickly) and straw, lumber from forests certified to be sustainably managed, ecology blocks, dimension stone, recycled stone, recycled metal, and other products that are non-toxic, reusable, renewable, and/or recyclable (e.g. Trass, Linoleum, sheep wool, panels made from paper flakes, compressed earth block, adobe, baked earth, rammed earth, clay, vermiculite, flax linen, sisal, seagrass, cork, expanded clay grains, coconut, wood fibre plates, calcium sand stone, concrete (high and ultra high performance, roman self-healing concrete [10]) , etc. [11] [12]) The EPA (Environmental Protection Agency) also suggests using recycled industrial goods, such as coal combustion products, foundry sand, and demolition debris in construction projects [13]

Polyurethane heavily reduces carbon emissions as well. Polyurethane blocks are being used instead of CMTs by companies like American Insulock. Polyurethane blocks provide more speed, less cost, and they are environmentally friendly. [14]

Building materials should be extracted and manufactured locally to the building site to minimize the energy embedded in their transportation. Where possible, building elements should be manufactured off-site and delivered to site, to maximise benefits of off-site manufacture including minimising waste, maximising recycling (because manufacture is in one location), high quality elements, better OHS management, less noise and dust.

Indoor environmental quality enhancement

See also: Indoor Air Quality

The Indoor Environmental Quality (IEQ) category in LEED standards, one of the five environmental categories, was created to provide comfort, well-being, and productivity of occupants. The LEED IEQ category addresses design and construction guidelines especially: indoor air quality (IAQ), thermal quality, and lighting quality. [15]

Indoor Air Quality seeks to reduce volatile organic compounds, or VOC's, and other air impurities such as microbial contaminants. Buildings rely on a properly designed HVAC system to provide adequate ventilation and air filtration as well as isolate operations (kitchens, dry cleaners, etc.) from other occupancies. During the design and construction process choosing construction materials and interior finish products with zero or low emissions will improve IAQ. Many building materials and cleaning/maintenance products emit toxic gases, such as VOC's and formaldehyde. These gases can have a detrimental impact on occupants' health and productivity as well. Avoiding these products will increase a building's IEQ.

Personal temperature and airflow control over the HVAC system coupled with a properly designed building envelope will also aid in increasing a building's thermal quality. Creating a high performance luminous environment through the careful integration of natural and artificial light sources will improve on the lighting quality of a structure. [9] [16]

Operations and maintenance optimization

No matter how sustainable a building may have been in its design and construction, it can only remain so if it is operated responsibly and maintained properly. Ensuring operations and maintenance(O&M) personnel are part of the project's planning and development process will help retain the green criteria designed at the onset of the project. [17] Every aspect of green building is integrated into the O&M phase of a building's life. The addition of new green technologies also falls on the O&M staff. Although the goal of waste reduction may be applied during the design, construction and demolition phases of a building's life-cycle, it is in the O&M phase that green practices such as recycling and air quality enhancement take place.

Waste reduction

Green architecture also seeks to reduce waste of energy, water and materials used during construction. For example, in California nearly 60% of the state's waste comes from commercial buildings [18] During the construction phase, one goal should be to reduce the amount of material going to landfills. Well-designed buildings also help reduce the amount of waste generated by the occupants as well, by providing on-site solutions such as compost bins to reduce matter going to landfills.

To reduce the impact on wells or water treatment plants, several options exist. "Greywater", wastewater from sources such as dishwashing or washing machines, can be used for subsurface irrigation, or if treated, for non-potable purposes, e.g., to flush toilets and wash cars. Rainwater collectors are used for similar purposes.

Centralized wastewater treatment systems can be costly and use a lot of energy. An alternative to this process is converting waste and wastewater into fertilizer, which avoids these costs and shows other benefits. By collecting human waste at the source and running it to a semi-centralized biogas plant with other biological waste, liquid fertilizer can be produced. This concept was demonstrated by a settlement in Lubeck Germany in the late 1990s. Practices like these provide soil with organic nutrients and create carbon sinks that remove carbon dioxide from the atmosphere, offsetting greenhouse gas emission. Producing artificial fertilizer is also more costly in energy than this process. [19]

Cost

The most criticized issue about constructing environmentally friendly buildings is the price. Photo-voltaics, new appliances, and modern technologies tend to cost more money. Most green buildings cost a premium of <2%, but yield 10 times as much over the entire life of the building. [20]

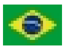
The stigma is between the knowledge of up-front cost vs. life-cycle cost. The savings in money come from more efficient use of utilities which result in decreased energy bills. Also, higher worker or student productivity can be factored into savings and cost deductions. Studies have shown over a 20 year life period, some green buildings have yielded $53 to $71 per square foot back on investment. [21]

It is projected that different sectors could save $130 Billion on energy bills. [22]

Regulation and operation

Many countries have developed their own standards for green building or energy efficiency for buildings. Above some examples of building environmental assessment tools currently in use:

-  Australia: Nabers [4] / Green Star [5]

-  Brazil: AQUA [6]

-  Canada: LEED Canada [7] / Green Globes [8]

-  China: GBAS [9]

- Finland: PromisE [10]

- France: HQE [11]

- Germany: DGNB [12] / CEPHEUS [13]

- Hong Kong: HKBEAM [14]

- India: GRIHA National Rating System developed by TERI, LEED India www.igbc.in

- Italy: Protocollo Itaca [15] / Green Building Counsil Italia [16]

- Malaysia: GBI Malaysia [17]

- Mexico

- Netherlands: BREEAM Netherlands [18]

- New Zealand: Green Star NZ [19]

- Philippines: BERDE / Philippine Green Building Council PHILGBC

- Portugal: Lider A [20]

- 
Singapore: Green Mark [21]

- 
South Africa: Green Star SA [22]

- 
Spain: VERDE

- 
Switzerland: Minergie [23]

- 
United States: LEED [24] / Living Building Challenge [25] / Green Globes [26] / Build it Green [27] / NAHB NGBS [28]

- 
United Kingdom: BREEAM [29]

International frameworks and assessment tools

IPCC Fourth Assessment Report [30]

Climate Change 2007, the Fourth Assessment Report (AR4) of the United Nations Intergovernmental Panel on Climate Change (IPCC), is the fourth in a series of such reports. The IPCC was established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) to assess scientific, technical and socio-economic information concerning climate change, its potential effects and options for adaptation and mitigation.

UNEP and Climate change [31]

UNEP works to facilitate the transition to low-carbon societies, support climate proofing efforts, improve understanding of climate change science, and raise public awareness about this global challenge.

GHG Indicator [32]

The GHG Indicator: UNEP Guidelines for Calculating Greenhouse Gas Emissions for Businesses and Non-Commercial Organizations

Agenda 21 [33]

Agenda 21 is a programme run by the United Nations (UN) related to sustainable development. It is a comprehensive blueprint of action to be taken globally, nationally and locally by organizations of the UN, governments, and major groups in every area in which humans impact on the environment. The number 21 refers to the 21st century.

FIDIC's PSM [34]

FIDIC's Project Sustainability Management Guidelines were created in order to assist project engineers and other stakeholders in setting sustainable development goals for their projects that are recognized and accepted by as being in the interests of society as a whole. The process is also intended to allow the alignment of project goals with local conditions and priorities and to assist those involved in managing projects to measure and verify their progress.

The PSM Guidelines are structured with Themes and Sub-Themes under the three main sustainability headings of Social, Environmental and Economic. For each individual Sub-Theme a core project indicator is defined along with guidance as to the relevance of that issue in the context of an individual project.

The Sustainability Reporting Framework provides guidance for organizations to use as the basis for disclosure about their sustainability performance, and also provides stakeholders a universally applicable, comparable framework in which to understand disclosed information.

The Reporting Framework contains the core product of the Sustainability Reporting Guidelines, as well as Protocols and Sector Supplements. The Guidelines are used as the basis for all reporting. They are the foundation upon which all other reporting guidance is based, and outline core content for reporting that is broadly relevant to all organizations regardless of size, sector, or location. The Guidelines contain principles and guidance as well as standard disclosures – including indicators – to outline a disclosure framework that organizations can voluntarily, flexibly, and incrementally, adopt.

Protocols underpin each indicator in the Guidelines and include definitions for key terms in the indicator, compilation methodologies, intended scope of the indicator, and other technical references.

Sector Supplements respond to the limits of a one-size-fits-all approach. Sector Supplements complement the use of the core Guidelines by capturing the unique set of sustainability issues faced by different sectors such as mining, automotive, banking, public agencies and others.

IPD Environment Code

The IPD Environment Code was launched in February 2008. The Code is intended as a good practice global standard for measuring the environmental performance of corporate buildings. Its aim is to accurately measure and manage the environmental impacts of corporate buildings and enable property executives to generate high quality, comparable performance information about their buildings anywhere in the world. The Code covers a wide range of building types (from offices to airports) and aims to inform and support the following;

- Creating an environmental strategy

- Inputting to real estate strategy

- Communicating a commitment to environmental improvement
- Creating performance targets
- Environmental improvement plans
- Performance assessment and measurement
- Life cycle assessments
- Acquisition and disposal of buildings
- Supplier management
- Information systems and data population
- Compliance with regulations
- Team and personal objectives

IPD estimate that it will take approximately three years to gather significant data to develop a robust set of baseline data that could be used across a typical corporate estate.

ISO 21931

ISO/TS 21931:2006, Sustainability in building construction—Framework for methods of assessment for environmental performance of construction works—Part 1: Buildings, is intended to provide a general framework for improving the quality and comparability of methods for assessing the environmental performance of buildings. It identifies and describes issues to be taken into account when using methods for the assessment of environmental performance for new or existing building properties in the design, construction, operation, refurbishment and deconstruction stages. It is not an assessment system in itself but is intended be used in conjunction with, and following the principles set out in, the ISO 14000 series of standards.

See also

- [redacted]nder Thomson, a pioneer in sustainable building
- [redacted]ative natural materials
- [redacted]w Delmar Hopkins
- [redacted]gy — high density ecological structures
- [redacted] solar
- [redacted]omous building
- [redacted]ng Codes Assistance Project
- [redacted]nstruction (building)
- [redacted]nsion stone
- [redacted]tics
- [redacted]bag construction
- [redacted]Craft House
- [redacted]ship
- [redacted]otel
- [redacted]uilding cluster (in Belgium)
- [redacted]onmental planning
- [redacted]y-plus-house
- [redacted]ean
- [redacted]ree Hab

- [redacted]xchange
- [redacted] Building Council
- [redacted] library
- [redacted] technology
- [redacted]sland effect
- [redacted]ater heat recycling
- [redacted]ting concrete forms
- [redacted]rship in Energy and Environmental Design
- [redacted] low-energy building techniques
- [redacted]nergy house
- [redacted]ey tables
- [redacted]l building
- [redacted]voltaics
- [redacted]ater harvesting
- [redacted]inable city
- [redacted]inable habitat
- [redacted]erifier
- [redacted]al green building
- [redacted]energy building

References

1. ^ a b U.S. Environmental Protection Agency. (October 28, 2009). Green Building Basic Information. Retrieved December 10, 2009, from http://www.epa.gov/greenbuilding/pubs/about.htm
2. ^ Hopkins, R. 2002. *A Natural Way of Building.* Transition Culture. Retrieved: 2007-03-30.
3. ^ Mao, X., Lu, H., & Li, Q. (2009). *International Conference on Management and Service Science, 2009. MASS '09.* , 1-5. doi:10.1109/ICMSS.2009.5303546

4. ^ • U.S. Environmental Protection Agency. (October 28, 2009). Green Building Home. Retrieved November 28, 2009, from http://www.epa.gov/greenbuilding/pubs/components.htm
5. ^ • WBDG Sustainable Committee. (August 18, 2009). Sustainable. Retrieved November 28, 2009, from http://www.wbdg.org/designsustainable.php
6. ^ Hegazy, T. (2002). Life-cycle stages of projects. Computer-Based Construction Project Management, 8.
7. ^ Pushkar, S., Becker, R., & Katz, A.(2005). A methodology for design of environmentally optimal buildings by variable grouping. *Building and Environment*, 40. doi:10.1016/j.buildenv.2004.09.004

8. ^ Simpson, J.R. Energy and Buildings, Improved Estimates of tree-shade effects on residential energy use, February 2002. [1] Retrieved:2008-04-30.
9. ^ a b California Integrated Waste Management Board. (January 23, 2008). Green Building Home Page. Retrieved November 28, 2009, from http://www.ciwmb.ca.gov/GREENBUILDING/basics.htm

10. ^ Roman concrete self-healing
11. ^ Duurzaam en Gezond Bouwen en Wonen by Hugo Vanderstadt
12. ^ Time:Cementing the future
13. ^ http://www.epa.gov/greenbuilding/pubs/components.htm#materials
14. ^ http://www.polyurethane.org/s_api/sec.asp?CID=815&DID=3428
15. ^ Lee YS, Guerin DA, Indoor environmental quality differences between office types in LEED-certified buildings in the US, Building and Environment (2009), doi:10.1016/j.buildenv.2009.10.019
16. ^ WBDG Sustainable Committee. (August 18, 2009). Sustainable. Retrieved October 28, 2009, from http://www.wbdg.org/design/ieq.php
17. ^ WBDG Sustainable Committee. (August 18, 2009). Sustainable. Retrieved November 28, 2009, from http://www.wbdg.org/design/optimize_om.php
18. ^ Kats, Greg; Alevantis Leon; Berman Adam; Mills Evan; Perlman, Jeff. The Cost and Financial Benefits of Green Buildings, October 2003 [2] Retrieved:November 3rd, 2008.
19. ^ Lange, Jorg; Grottker, Mathias; Otterpohl, Ralf. Water Science and Technology,

Sustainable Water and Waste Management In Urban Areas, June 1998. [3] Retrieved:April 30, 2008.

20. ^ Kats, Greg, Leon Alevantis, Adam Berman, Evan Mills, Jeff Perlman. The Cost and Financial Benefits of Green Buildings, November 3rd, 2008.
21. ^ Langdon, Davis. The Cost of Green Revisited. Publication. 2007.
22. ^ Fedrizzi, Rick,"Intro – What LEED Measures." United States Green Building Council, October 11, 2009.