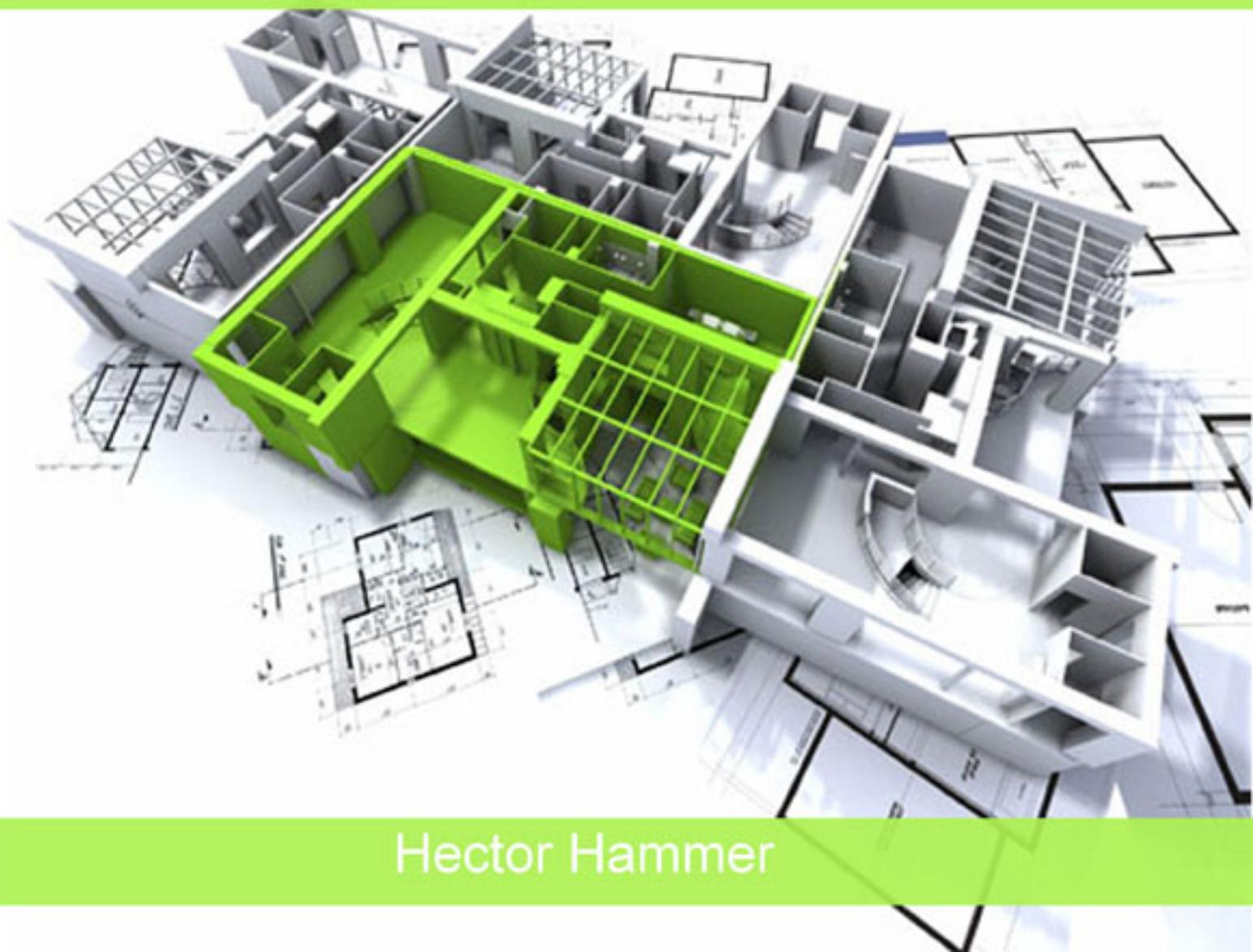


# Green Building Engineering



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## Chapter- 1

# Green Building



US EPA Kansas City Science & Technology Center. This facility features the following green attributes:

- \*LEED 2.0 Gold certified
- \*Green Power
- \*Native Landscaping

**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 demolition. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort.

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

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. Other related topics include sustainable design and green architecture. Green building does not specifically address the issue of the retrofitting existing homes.

## Reducing environmental impact

Green building practices aim to reduce the environmental impact of new 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 building sector alone accounts for 30-40 percent of global energy use. Over 80 percent of the environmentally harmful emissions from buildings are due to energy consumption during the times when the buildings are in use. Green building does not typically include the concept of renovations although many of the 2050 homes are already built and UK homes account for 30% of UK Carbon Emissions. Domestic energy improvement targets of 20% between now and 2010, and again by a further 20% between 2010 and 2020 have been suggested by the UK government. 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. According to the UK Green Building Council, existing buildings account for 17% of the UK's total carbon emissions.

## Goals of green building



the Blu Homes mkSolaire, a green building designed by Michelle Kaufmann.

The concept of sustainable development can be traced to the energy (especially fossil oil) crisis and the environment pollution concern in the 1970s. 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 new 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. 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. In designing environmentally optimal buildings, the objective is to minimize 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.

### **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 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**

Reducing water consumption and protecting water quality are key objectives in sustainable building. One critical issue of water consumption is that in many areas, 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.

## **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) , etc.) The EPA (Environmental Protection Agency) also suggests using recycled industrial goods, such as coal combustion products, foundry sand, and demolition debris in construction projects. 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**

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.

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.

### **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. 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. 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.

## Cost and payoff

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. 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. It is projected that different sectors could save \$130 Billion on 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. Confirming the rentability of green building investments, further studies of the commercial real estate market have found that LEED and Energy Star certified buildings achieve significantly higher rents, sale prices and occupancy rates as well as lower capitalization rates potentially reflecting lower investment risk.

## Regulation and operation

Many countries have developed their own standards for green building or energy efficiency for buildings. Some of the major building environmental assessment tools currently in use include:

-  Australia: Nabers / Green Star
-  Brazil: AQUA / LEED Brasil
-  Canada: LEED Canada / Green Globes
-  China: GBAS
-  Finland: Promise
-  France: HQE
-  Germany: DGNB / CEPHEUS
-  Hong Kong: HKBEAM
-  India: Indian Green Building Council (IGBC) / GRIHA
-  Italy: Protocollo Itaca / Green Building Council Italia
-  Japan: CASBEE
-  Malaysia: GBI Malaysia

-  Mexico: LEED Mexico
-  Netherlands: BREEAM Netherlands
-  New Zealand: Green Star NZ
-  Philippines: BERDE / Philippine Green Building Council
-  Portugal: Lider A
-  Singapore: Green Mark
-  South Africa: Green Star SA
-  Spain: VERDE
-  Switzerland: Minergie
-  United States: LEED / Living Building Challenge / Green Globes / Build it Green / NAHB NGBS / International Green Construction Code International Green Construction Code (IGCC)
-  United Kingdom: BREEAM
-  United Arab Emirates: Estidama
-  IAPGSA Pakistan Institute of Architecture Pakistan Green Sustainable Architecture

## International frameworks and assessment tools

### IPCC Fourth Assessment Report

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

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

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

### Agenda 21

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**

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.

# Sustainable Design

**Sustainable design** (also called environmental design, environmentally sustainable design, environmentally conscious design, etc.) is the philosophy of designing physical objects, the built environment, and services to comply with the principles of economic, social, and ecological sustainability.

## Intentions

The intention of sustainable design is to "eliminate negative environmental impact completely through skillful, sensitive design". Manifestations of sustainable design require no non-renewable resources, impact the environment minimally, and relate people with the natural environment.

## Applications

Applications of this philosophy range from the microcosm — small objects for everyday use, through to the macrocosm — buildings, cities, and the Earth's physical surface. It is a philosophy that can be applied in the fields of architecture, landscape architecture, urban design, urban planning, engineering, graphic design, industrial design, interior design, and fashion design.

Sustainable design is mostly a general reaction to global environmental crises, the rapid growth of economic activity and human population, depletion of natural resources, damage to ecosystems, and loss of biodiversity.

The limits of sustainable design are reducing. Whole earth impacts are beginning to be considered because growth in goods and services is consistently outpacing gains in efficiency. As a result, the net effect of sustainable design to date has been to simply improve the efficiency of rapidly increasing impacts. The present approach, which focuses on the efficiency of delivering individual goods and services, does not solve this problem. The basic dilemmas include: the increasing complexity of efficiency improvements; the difficulty of implementing new technologies in societies built around

old ones; that physical impacts of delivering goods and services are not localized, but are distributed throughout the economies; and that the scale of resource use is growing and not stabilizing.

## **Sustainable Design Principles**

While the practical application varies among disciplines, some common principles are as follows:

- Low-impact materials: choose non-toxic, sustainably produced or recycled materials which require little energy to process
- Energy efficiency: use manufacturing processes and produce products which require less energy
- Quality and durability: longer-lasting and better-functioning products will have to be replaced less frequently, reducing the impacts of producing replacements
- Design for reuse and recycling: "Products, processes, and systems should be designed for performance in a commercial 'afterlife'."
- Design Impact Measures for total carbon footprint and life-cycle assessment for any resource used are increasingly required and available. Many are complex, but some give quick and accurate whole-earth estimates of impacts. One measure estimates any spending as consuming an average economic share of global energy use of 8,000btu per dollar and producing CO<sub>2</sub> at the average rate of 0.57 kg of CO<sub>2</sub> per dollar (1995 dollars US) from DOE figures.
- Sustainable Design Standards and project design guides are also increasingly available and are vigorously being developed by a wide array of private organizations and individuals. There is also a large body of new methods emerging from the rapid development of what has become known as 'sustainability science' promoted by a wide variety of educational and governmental institutions.
- Biomimicry: "redesigning industrial systems on biological lines ... enabling the constant reuse of materials in continuous closed cycles..."
- Service substitution: shifting the mode of consumption from personal ownership of products to provision of services which provide similar functions, e.g., from a private automobile to a carsharing service. Such a system promotes minimal resource use per unit of consumption (e.g., per trip driven).
- Renewability: materials should come from nearby (local or bioregional), sustainably managed renewable sources that can be composted when their usefulness has been exhausted.
- Healthy Buildings: sustainable building design aims to create buildings that are not harmful to their occupants nor to the larger environment. An important emphasis is on indoor environmental quality, especially indoor air quality.
- Robust eco-design: robust design principles are applied to the design of a pollution sources).

### **Bill of Rights for the Planet**

A model of the new design principles necessary for sustainability is exemplified by the "Bill of Rights for the Planet" or "Hannover Principles" - developed by William McDonough Architects for EXPO 2000 that was held in Hannover, Germany.

*The Bill of Rights:*

1. Insist on the right of humanity and nature to co-exist in a healthy, supportive, diverse, and sustainable condition.
2. Recognize Interdependence. The elements of human design interact with and depend on the natural world, with broad and diverse implications at every scale. Expand design considerations to recognizing even distant effects.
3. Respect relationships between spirit and matter. Consider all aspects of human settlement including community, dwelling, industry, and trade in terms of existing and evolving connections between spiritual and material consciousness.
4. Accept responsibility for the consequences of design decisions upon human well-being, the viability of natural systems, and their right to co-exist.
5. Create safe objects of long-term value. Do not burden future generations with requirements for maintenance or vigilant administration of potential danger due to the careless creations of products, processes, or standards.
6. 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.
7. Rely on natural energy flows. Human designs should, like the living world, derive their creative forces from perpetual solar income. Incorporate this energy efficiently and safely for responsible use.
8. Understand the limitations of design. No human creation lasts forever and design does not solve all problems. Those who create and plan should practice humility in the face of nature. Treat nature as a model and mentor, not an inconvenience to be evaded or controlled.
9. Seek constant improvement by the sharing of knowledge. Encourage direct and open communication between colleagues, patrons, manufacturers and users to link long term sustainable considerations with ethical responsibility, and re-establish the integral relationship between natural processes and human activity.

These principles were adopted by the World Congress of the International Union of Architects (UIA) in June 1993 at the American Institute of Architect's (AIA) Expo 93 in Chicago. Further, the AIA and UIA signed a "Declaration of Interdependence for a Sustainable Future." In summary, the declaration states that today's society is degrading its environment and that the AIA, UIA, and their members are committed to:

- Placing environmental and social sustainability at the core of practices and professional responsibilities
- Developing and continually improving practices, procedures, products, services, and standards for sustainable design
- Educating the building industry, clients, and the general public about the importance of sustainable design

- Working to change policies, regulations, and standards in government and business so that sustainable design will become the fully supported standard practice
- Bringing the existing built environment up to sustainable design standards

In addition, the Interprofessional Council on Environmental Design (ICED), a coalition of architectural, landscape architectural, and engineering organizations, developed a vision statement in an attempt to foster a team approach to sustainable design. ICED states: The ethics, education and practices of our professions will be directed to shape a sustainable future. . . . To achieve this vision we will join . . . as a multidisciplinary partnership."

These activities are an indication that the concept of sustainable design is being supported on a global and interprofessional scale and that the ultimate goal is to become more environmentally responsive. The world needs facilities that are more energy efficient and that promote conservation and recycling of natural and economic resources.

## Conceptual Problems to Solve

- **Diminishing Returns:** The principle that all directions of progress run out, ending with diminishing returns, is evident in the typical 'S' curve of The Technology Life Cycle and in the useful life of any system as discussed in Industrial Ecology and Life Cycle Assessment. It's as reliable an expectation as any principle of science that diminishing returns signal natural limits. Common office and business management practice is to read diminishing returns in any direction of effort as an indication of diminishing opportunity, a potential for accelerating their decline and signal to turn elsewhere.
- **Unsustainable Investment:** A problem arises when the limits of a resource are hard to see, so increasing investment in response to diminishing returns may seem profitable as in the Tragedy of the Commons, but may lead to a collapse. This problem of increasing investment in diminishing resources has also been studied in relation to the causes of civilization collapse by Joseph Tainter among others. This natural error in investment policy contributed to the collapse of both the Roman and Mayan, among others. Relieving over-stressed resources requires reducing pressure on them, not continually increasing it whether more efficiently or not

## Waste Prevention

**Negative Effects of Waste** About 80 million tonnes of waste in total are generated in the U.K. alone, for example, each year. And with reference to only household waste, between 1991/92 and 2007/08, each person in England generated an average of 1.35 pounds of waste per day.

Experience has now shown that there is no completely safe method of waste disposal. All forms of disposal have negative impacts on the environment, public health, and local economies. Landfills have contaminated drinking water. Garbage burned in incinerators has poisoned air, soil, and water. The majority of water treatment systems change the local ecology. Attempts to control or manage wastes after they are produced fail to eliminate environmental impacts.

The toxic components of household products pose serious health risks and aggravate the trash problem. In the U.S., about eight pounds in every ton of household garbage contains toxic materials, such as lead, cadmium, and mercury from batteries, insect sprays, nail polish, cleaners, and other products. When burned or buried, toxic materials also pose a serious threat to public health and the environment.

The only way to avoid environmental harm from waste is to prevent its generation. Pollution prevention means changing the way activities are conducted and eliminating the source of the problem. It does not mean doing without, but doing differently. For example, preventing waste pollution from litter caused by disposable beverage containers does not mean doing without beverages; it just means using refillable bottles.

**Waste Prevention Strategies** In planning for facilities, a comprehensive design strategy is needed for preventing generation of solid waste. A good garbage prevention strategy would require that everything brought into a facility be recycled for reuse or recycled back into the environment through biodegradation. This would mean a greater reliance on natural materials or products that are compatible with the environment.

Any resource-related development is going to have two basic sources of solid waste — materials purchased and used by the facility and those brought into the facility by visitors. The following waste prevention strategies apply to both, although different approaches will be needed for implementation:

- use products that minimize waste and are nontoxic
- compost or anaerobically digest biodegradable wastes
- reuse materials onsite or collect suitable materials for offsite recycling

## **Examples of sustainable design**

### **Sustainable planning**



Cohousing community illustrating greenspace preservation, tightly clustered housing, and parking on periphery, Ann Arbor, Michigan, 2003.

Urban planners that are interested in achieving sustainable development or sustainable cities use various design principles and techniques when designing cities and their infrastructure. These include Smart Growth theory, Transit-oriented development, sustainable urban infrastructure and New Urbanism. Smart Growth is an urban planning and transportation theory that concentrates growth in infill sites within the existing infrastructure of a city or town to avoid urban sprawl; and advocates compact, transit-oriented development, walkable, bicycle-friendly land use, including mixed-use development with a range of housing choices. Transit-oriented development attempts to maximise access to public transport and thereby reduce the need for private vehicles. Public transport is considered a form of Sustainable urban infrastructure, which is a design approach which promotes protected areas, energy-efficient buildings, wildlife corridors and distributed, rather than centralized, power generation and waste water treatment. New Urbanism is more of a social and aesthetic urban design movement than a green one, but it does emphasize diversity of land use and population, as well as walkable communities which inherently reduce the need for automotive travel.

Both urban and rural planning can benefit from including sustainability as a central criterion when laying out roads, streets, buildings and other components of the built environment. Conventional planning practice often ignores or discounts the natural configuration of the land during the planning stages, potentially causing ecological damage such as the stagnation of streams, mudslides, soil erosion, flooding and pollution. Applying methods such as scientific modelling to planned building projects can draw attention to problems before construction begins, helping to minimise damage to the natural environment.

Cohousing is an approach to planning based on the idea of intentional communities. Such projects often prioritize common space over private space resulting in grouped structures that preserve more of the surrounding environment.

Watershed assessment of carrying capacity; estuary, riparian zone restoration and groundwater recharge for hydrologic cycle viability; and other opportunities and issues about Water and the environment show that the foundation of smart growth lies in the protection and preservation of water resources. The total amount of precipitation landing

on the surface of a community becomes the supply for the inhabitants. This supply amount then dictates the carrying capacity - the potential population - as supported by the "water crop."

## **Sustainable architecture**

Sustainable architecture is the design of sustainable buildings. Sustainable architecture attempts to reduce the collective environmental impacts during the production of building components, during the construction process, as well as during the lifecycle of the building (heating, electricity use, carpet cleaning etc.) This design practice emphasizes efficiency of heating and cooling systems; alternative energy sources such as solar hot water, appropriate building siting, reused or recycled building materials; on-site power generation - solar technology, ground source heat pumps, wind power; rainwater harvesting for gardening, washing and aquifer recharge; and on-site waste management such as green roofs that filter and control stormwater runoff. This requires close cooperation of the design team, the architects, the engineers, and the client at all project stages, from site selection, scheme formation, material selection and procurement, to project implementation.

Sustainable architects design with sustainable living in mind. Sustainable vs green design is the challenge that designs not only reflect healthy processes and uses but are powered by renewable energies and site specific resources. A test for sustainable design is — can the design function for its intended use without fossil fuel — unplugged. This challenge suggests architects and planners design solutions that can function without pollution rather than just reducing pollution. As technology progresses in architecture and design theories and as examples are built and tested, architects will soon be able to create not only passive, null-emission buildings, but rather be able to integrate the entire power system into the building design. In 2004 the 59 home housing community, the Solar Settlement, and a 60,000 sq ft (5,600 m<sup>2</sup>) integrated retail, commercial and residential building, the Sun Ship, were completed by architect Rolf Disch in Freiburg, Germany. The Solar Settlement is the first housing community world wide in which every home, all 59, produce a positive energy balance.

## **Sustainable landscape and garden design**

**Sustainable landscape architecture** is a category of sustainable design and energy-efficient landscaping concerned with the planning and design of outdoor space. Design techniques include planting trees to shade buildings from the sun or protect them from wind, using local materials, on-site composting and chipping to reduce green waste hauling, and also may involve using drought-resistant plantings in arid areas (xeriscaping) and buying stock from local growers to avoid energy use in transportation.

## **Sustainable graphic design**

Sustainable graphic design considers the environmental impacts of graphic design products (such as packaging, printed materials, publications, etc.) throughout a life cycle

that includes: raw material; transformation; manufacturing; transportation; use; and disposal. Techniques for sustainable graphic design include: reducing the amount of materials required for production; using paper and materials made with recycled, post-consumer waste; printing with low-VOC inks; and using production and distribution methods that require the least amount of transport.

## **Sustainable Agriculture**

Sustainable agriculture adheres to three main goals:

- environmental health,
- economic profitability,
- social and economic equity.

A variety of philosophies, policies and practices have contributed to these goals. People in many different capacities, from farmers to consumers, have shared this vision and contributed to it. Despite the diversity of people and perspectives, the following themes commonly weave through definitions of sustainable agriculture.

There are strenuous discussions — among others by the agricultural sector and authorities — if existing pesticide protocols and methods of soil conservation adequately protect topsoil and wildlife. Doubt has risen if these are sustainable, and if agrarian reforms would permit an efficient agriculture with fewer pesticides, therefore reducing the damage to the ecosystem.

## **Domestic machinery and furniture**



Stainless Steel Table with FSC Teca Wood - Brazil sustainable design. Stainless is 100% recyclable and teca wood comes environmental friendly reforestation

Automobiles, home appliances and furnitures can be designed for repair and disassembly (for recycling), and constructed from recyclable materials such as steel, aluminum and glass, and renewable materials, such as Zelfo, wood and plastics from natural feedstocks. Careful selection of materials and manufacturing processes can often create products comparable in price and performance to non-sustainable products. Even mild design efforts can greatly increase the sustainable content of manufactured items.

### **Improvements to heating, cooling, ventilation and water heating**

- Absorption refrigerator
- Annualized geothermal solar
- Earth cooling tubes
- Geothermal heat pump
- Heat recovery ventilation
- Hot water heat recycling
- Passive cooling
- Renewable heat
- Seasonal thermal storage
- Solar air conditioning
- Solar hot water

## **Disposable products**

Detergents, newspapers and other disposable items can be designed to decompose, in the presence of air, water and common soil organisms. The current challenge in this area is to design such items in attractive colors, at costs as low as competing items. Since most such items end up in landfills, protected from air and water, the utility of such disposable products is debated.

## **Eco fashion and home accessories**

Creative designers and artists are perhaps the most inventive when it comes to upcycling or creating new products from old waste. A growing number of designers upcycle waste materials such as car window glass and recycled ceramics, textile offcuts from upholstery companies, and even decommissioned fire hose to make belts and bags. Whilst accessories may seem trivial when pitted against green scientific breakthroughs; the ability of fashion and retail to influence and inspire consumer behaviour should not be underestimated. Eco design may also use bi-products of industry, reducing the amount of waste being dumped in landfill, or may harness new sustainable materials or production techniques e.g. fabric made from recycled PET plastic bottles or bamboo textiles.

## **Energy Sector**

Sustainable technology in the energy sector is based on utilizing renewable sources of energy such as solar, wind, hydro, bioenergy, geothermal, and hydrogen. Wind energy is the world's fastest growing energy source; it has been in use for centuries in Europe and more recently in the United States and other nations. Wind energy is captured through the use of wind turbines that generate and transfer electricity for utilities, homeowners and remote villages. Solar power can be harnessed through photovoltaics, concentrating solar, or solar hot water and is also a rapidly growing energy source.

The availability, potential, and feasibility of primary renewable energy resources must be analyzed early in the planning process as part of a comprehensive energy plan. The plan must justify energy demand and supply and assess the actual costs and benefits to the local, regional, and global environments. Responsible energy use is fundamental to sustainable development and a sustainable future. Energy management must balance justifiable energy demand with appropriate energy supply. The process couples energy awareness, energy conservation, and energy efficiency with the use of primary renewable energy resources.

## **Water Sector**

Sustainable water technologies have become an important industry segment with several companies now providing important and scalable solutions to supply water in a sustainable manner.

Beyond the use of certain technologies, Sustainable Design in Water Management also consists very importantly in correct implementation of concepts. Among one of these principal concepts is the fact normally in developed countries 100% of water destined for consumption, that is not necessarily for drinking purposes, is of potable water quality. This concept of differentiating qualities of water for different purposes has been called "fit-for-purpose". This more rational use of water achieves several economies, that are not only related to water itself, but also the consumption of energy, as to achieve water of drinking quality can be extremely energy intensive for several reasons.

## **Sustainable technologies**

Sustainable technologies use less energy, fewer limited resources, do not deplete natural resources, do not directly or indirectly pollute the environment, and can be reused or recycled at the end of their useful life. There is a significant overlap with appropriate technology, which emphasizes the suitability of technology to the context, in particular considering the needs of people in developing countries. However, the most appropriate technology may not be the most sustainable one; and a sustainable technology may have high cost or maintenance requirements that make it unsuitable as an "appropriate technology," as that term is commonly used.

## **Encouraging sustainability**



Training meeting with factory workers in a stainless steel ecodesign company from Rio de Janeiro - Brazil

The Passivhaus-Institut promotes and establishes standards for the Passive House - Passivhaus international program for Low-energy houses and other low-energy building techniques and structures.

The use of sustainable technologies may be encouraged through means such as reducing the capacity of the electrical cable supplying a home, such as Australia's Crystal Waters Village. In some cases the electricity supplier charges a higher rate for the energy used when the capacity of the supply is increased.

## **Terminology**

In some countries the term *sustainable design* is known as Ecodesign, green design or environmental design. Ecodesign as meant by Victor Papanek, did include social design and social aspects. Over the past years the terms *sustainable design* and *design for sustainability* — besides other new terms — became more accepted globally, including the triple bottom line (people, planet and profit).

# Sustainable Architecture



Sustainable portable classroom design proposal

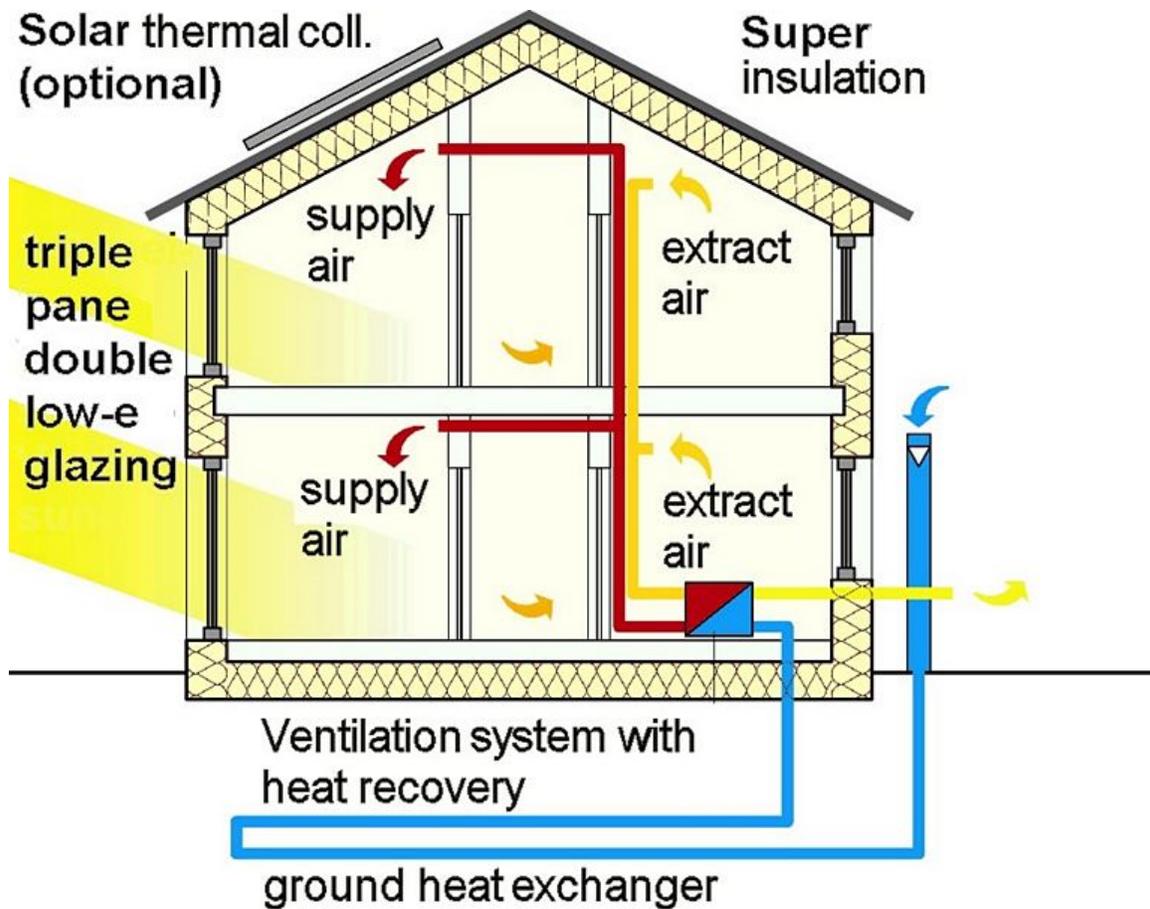
**Sustainable architecture** is a general term that describes environmentally conscious design techniques in the field of architecture. Sustainable architecture is framed by the larger discussion of sustainability and the pressing economic and political issues of our world. In the broad context, sustainable architecture seeks to minimize the negative

environmental impact of buildings by enhancing efficiency and moderation in the use of materials, energy, and development space. Most simply, the idea of sustainability, or ecological design, is to ensure that our actions and decisions today do not inhibit the opportunities of future generations. This term can be used to describe an energy and ecologically conscious approach to the design of the built environment.

## **Sustainable energy use**



K2 sustainable apartments in Windsor, Victoria, Australia by Hansen Yuncken (2006) features passive solar design, recycled and sustainable materials, photovoltaic cells, wastewater treatment, rainwater collection and solar hot water.



The passivhaus standard combines a variety of techniques and technologies to achieve ultra-low energy use.



Following its destruction by a tornado in 2007, the town of Greensburg, Kansas (USA) elected to rebuild to highly stringent LEED Platinum environmental standards. Shown is the town's new art center, which integrates its own solar panels and wind generators for energy self-sufficiency.

Energy efficiency over the entire life cycle of a building is the single most important goal of sustainable architecture. Architects use many different techniques to reduce the energy needs of buildings and increase their ability to capture or generate their own energy.

## **Heating, Ventilation and Cooling System Efficiency**

The most important and cost effective element of an efficient heating, ventilating, and air conditioning (HVAC) system is a well insulated building. A more efficient building requires less heat generating or dissipating power, but may require more ventilation capacity to expel polluted indoor air.

Significant amounts of energy are flushed out of buildings in the water, air and compost streams. Off the shelf, on-site energy recycling technologies can effectively recapture energy from waste hot water and stale air and transfer that energy into incoming fresh cold water or fresh air. Recapture of energy for uses other than gardening from compost leaving buildings requires centralized anaerobic digesters.

Site and building orientation have some major effects on a building's HVAC efficiency.

Passive solar building design allows buildings to harness the energy of the sun efficiently without the use of any active solar mechanisms such as photovoltaic cells or solar hot water panels. Typically passive solar building designs incorporate materials with high thermal mass that retain heat effectively and strong insulation that works to prevent heat escape. Low energy designs also requires the use of solar shading, by means of awnings, blinds or shutters, to relieve the solar heat gain in summer and to reduce the need for artificial cooling. In addition, low energy buildings typically have a very low surface area to volume ratio to minimize heat loss. This means that sprawling multi-winged building designs (often thought to look more "organic") are often avoided in favor of more centralized structures. Traditional cold climate buildings such as American colonial saltbox designs provide a good historical model for centralized heat efficiency in a small scale building.

Windows are placed to maximize the input of heat-creating light while minimizing the loss of heat through glass, a poor insulator. In the northern hemisphere this usually involves installing a large number of south-facing windows to collect direct sun and severely restricting the number of north-facing windows. Certain window types, such as double or triple glazed insulated windows with gas filled spaces and low emissivity (low-E) coatings, provide much better insulation than single-pane glass windows. Preventing excess solar gain by means of solar shading devices in the summer months is important to reduce cooling needs. Deciduous trees are often planted in front of windows to block excessive sun in summer with their leaves but allow light through in winter when their leaves fall off. Louvers or light shelves are installed to allow the sunlight in during the winter (when the sun is lower in the sky) and keep it out in the summer (when the sun is high in the sky). Coniferous or evergreen plants are often planted to the north of buildings to shield against cold north winds.

In colder climates, heating systems are a primary focus for sustainable architecture because they are typically one of the largest single energy drains in buildings.

In warmer climates where cooling is a primary concern, passive solar designs can also be very effective. Masonry building materials with high thermal mass are very valuable for retaining the cool temperatures of night throughout the day. In addition builders often opt for sprawling single story structures in order to maximize surface area and heat loss. Buildings are often designed to capture and channel existing winds, particularly the especially cool winds coming from nearby bodies of water. Many of these valuable strategies are employed in some way by the traditional architecture of warm regions, such as south-western mission buildings.

In climates with four seasons, an integrated energy system will increase in efficiency: when the building is well insulated, when it is sited to work with the forces of nature, when heat is recaptured (to be used immediately or stored), when the heat plant relying on fossil fuels or electricity is greater than 100% efficient, and when renewable energy is utilized.

## **Renewable energy generation**

### **Solar Panels**

Active solar devices such as photovoltaic solar panels help to provide sustainable electricity for any use. Electrical output of a solar panel is dependent on orientation, efficiency, latitude, and climate—solar gain varies even at the same latitude. Typical efficiencies for commercially available PV panels range from 4% to 28%. The low efficiency of certain photovoltaic panels can significantly affect the payback period of their installation. A good rule of thumb for the cost of installing solar panels is roughly about \$4.30/Watt.

Roofs are often angled toward the sun to allow photovoltaic panels to collect at maximum efficiency. For any solar panel, a true-south facing orientation maximizes yield. If true-south is not possible, solar panels can produce adequate energy if aligned within 30° of south. However, at higher latitudes, winter energy yield will be significantly reduced for non-south orientation.

To maximize efficiency in winter, the collector should be angled above horizontal Latitude + 15°. To maximize efficiency in summer, the angle should be Latitude - 15°. However, for an annual maximum production, the angle of the panel above horizontal should be equal to its latitude.

### **Wind Turbines**

Undersized wind turbines (normal turbines are often over 250 feet) may have been oversold and do not always provide the returns promised, particularly for North American households. The use of undersized wind turbines in energy production in

sustainable structures requires the consideration of many factors. In considering costs, small wind systems are generally more expensive than larger wind turbines relative to the amount of energy they produce. For small wind turbines, maintenance costs can be a deciding factor at sites with marginal wind-harnessing capabilities. At low-wind sites, maintenance can consume much of a small wind turbine's revenue. Wind turbines begin operating when winds reach 8 mph, achieve energy production capacity at speeds of 32-37 mph, and shut off to avoid damage at speeds exceeding 55 mph. The energy potential of a wind turbine is proportional to the square of the length of its blades and to the cube of the speed at which its blades spin. Though wind turbines are available that can supplement power for a single building, because of these factors, the efficiency of the wind turbine depends much upon the wind conditions at the building site. For these reasons, for wind turbines to be at all efficient, they must be installed at locations that are known to receive a constant amount of wind (with average wind speeds of more than 15 mph), rather than locations that receive wind sporadically. A small wind turbine can be installed on a roof. Installation issues then include the strength of the roof, vibration, and the turbulence caused by the roof ledge. Small-scale rooftop wind turbines have been known to be able to generate power from 10% to up to 25% of the electricity required of a regular domestic household dwelling. Turbines for residential scale use are available. They are usually approximately 7 feet (2 m) to 25 feet (8 m) in diameter and produce electricity at a rate of 900 watts to 10,000 watts at their tested wind speed. In the United States, residential wind turbines with outputs of 2-10 kW, typically cost between \$12,000 and \$55,000 installed (\$6 per watt), although there are incentives and rebates available in 19 states that can reduce the purchase price for homeowners by up to 50 percent, to (\$3 per watt).

### **Solar Water Heating**

Solar water heaters—also called solar domestic hot water systems—can be a cost-effective way to generate hot water for your home. They can be used in any climate, and the fuel they use—sunshine—is free.

There are two types of solar water systems- active and passive. An active solar collector system will cost approximately \$2,500 to \$3,500 installed and produce about 80 to 100 gallons of hot water per day. A passive system will cost about \$1,000 to \$2,000 installed but will have a lower capacity.

There are also two types of circulation, direct circulation systems and indirect circulation systems. Direct circulation systems loop the domestic water through the panels. They should not be used in climates with temperatures below freezing. Indirect circulation loops glycol or some other fluid through the solar panels and uses a heat exchanger to heat up the domestic water.

The two most common types of collector panels are Flat-Plate and Evacuated-tube. The two work similarly except that evacuated tubes do not convectively lose heat, which greatly improves their efficiency (5%-25% more efficient). With these higher

efficiencies, Evacuated-tube solar collectors can also produce higher-temperature space heating, and even higher temperatures for absorption cooling systems.

Electric-resistance water heaters that are common in homes today have an electrical demand around 4500 kW·h/year. With the use of solar collectors, the energy use is cut in half. The up-front cost of installing solar collectors is high, but with the annual energy savings, payback periods are relatively short.

## **Heat Pumps**

Air-source heat pumps (ASHP) can be thought of as reversible air conditioners. Like an air conditioner, an ASHP can take heat from a relatively cool space (e.g. a house at 70°F) and dump it into a hot place (e.g. outside at 85°F). However, unlike an air conditioner, the condenser and evaporator of an ASHP can switch roles and absorb heat from the cool outside air and dump it into a warm house.

Air-source heat pumps are inexpensive relative to other heat pump systems. However, the efficiency of air-source heat pumps decline when the outdoor temperature is very cold or very hot; therefore, they are only really applicable in temperate climates.

For areas not located in temperate climates, ground-source (or geothermal) heat pumps provide an efficient alternative. The difference between the two heat pumps is that the ground-source has one of its heat exchangers placed underground—usually in a horizontal or vertical arrangement. Ground-source takes advantage of the relatively constant, mild temperatures underground, which means their efficiencies can be much greater than that of an air-source heat pump. The in-ground heat exchanger generally needs a considerable amount of area. Designers have placed them in an open area next to the building or underneath a parking lot.

Energy Star ground-source heat pumps can be 40% to 60% more efficient than their air-source counterparts. They are also quieter and can also be applied to other functions like domestic hot water heating.

In terms of initial cost, the ground-source heat pump system costs about twice as much as a standard air-source heat pump to be installed. However, the up-front costs can be more than offset by the decrease in energy costs. The reduction in energy costs is especially apparent in areas with typically hot summers and cold winters.

Other types of heat pumps are water-source and air-earth. If the building is located near a body of water, the pond or lake could be used as a heat source or sink. Air-earth heat pumps circulate the building's air through underground ducts. With higher fan power requirements and inefficient heat transfer, Air-earth heat pumps are generally not practical for major construction.

## **Sustainable building materials**

Some examples of sustainable building materials include recycled denim or blown-in fiber glass insulation, sustainably harvested wood, Trass, Linoleum, sheep wool, concrete (high and ultra high performance, roman self-healing concrete), panels made from paper flakes, baked earth, rammed earth, clay, vermiculite, flax linnen, sisal, seegrass, cork, expanded clay grains, coconut, wood fibre plates, calcium sand stone, locally obtained stone and rock, and bamboo, which is one of the strongest and fastest growing woody plants, and non-toxic low-VOC glues and paints.

## Recycled Materials



Recycling items for building

Some sustainable architecture incorporates the use of recycled or second hand materials, such as reclaimed lumber. The reduction in use of new materials creates a corresponding reduction in embodied energy (energy used in the production of materials). Often sustainable architects attempt to retro-fit old structures to serve new needs in order to avoid unnecessary development. Architectural salvage and reclaimed materials are used when appropriate. When older buildings are demolished, frequently any good wood is reclaimed, renewed, and sold as flooring. Any good dimension stone is similarly reclaimed. Many other parts are reused as well, such as doors, windows, mantels, and hardware, thus reducing the consumption of new goods. When new materials are employed, green designers look for materials that are rapidly replenished, such as bamboo, which can be harvested for commercial use after only 6 years of growth, sorghum or wheat straw, both of which are waste material that can be pressed into panels, or cork oak, in which only the outer bark is removed for use, thus preserving the tree. When possible, building materials may be gleaned from the site itself; for example, if a new structure is being constructed in a wooded area, wood from the trees which were cut to make room for the building would be re-used as part of the building itself.

### **Lower Volatile Organic Compounds**

Low-impact building materials are used wherever feasible: for example, insulation may be made from low VOC (volatile organic compound)-emitting materials such as recycled denim or cellulose insulation, rather than the building insulation materials that may contain carcinogenic or toxic materials such as formaldehyde. To discourage insect damage, these alternate insulation materials may be treated with boric acid. Organic or milk-based paints may be used. However, a common fallacy is that "green" materials are always better for the health of occupants or the environment. Many harmful substances (including formaldehyde, arsenic, and asbestos) are naturally occurring and are not without their histories of use with the best of intentions. A study of emissions from materials by the State of California has shown that there are some green materials that have substantial emissions whereas some more "traditional" materials actually were lower emitters. Thus, the subject of emissions must be carefully investigated before concluding that natural materials are always the healthiest alternatives for occupants and for the Earth.

Volatile organic compounds (VOC) can be found in any indoor environment coming from a variety of different sources. VOCs have a high vapor pressure and low water solubility and are suspected of causing sick building syndrome type symptoms. This is because many VOCs have been known to cause sensory irritation and central nervous system symptoms characteristic to sick building syndrome, indoor concentrations of VOCs are higher than in the outdoor atmosphere, and when there are many VOCs present, they can cause additive and multiplicative effects.

Green products are usually considered to contain fewer VOCs and be better for human and environmental health. A case study conducted by the Department of Civil, Architectural, and Environmental Engineering at the University of Miami that compared three green products and their non-green counterparts found that even though both the

green products and the non-green counterparts both emitted levels of VOCs, the amount and intensity of the VOCs emitted from the green products were much safer and comfortable for human exposure.

## **Waste management**

Waste takes the form of spent or useless materials generated from households and businesses, construction and demolition processes, and manufacturing and agricultural industries. These materials are loosely categorized as municipal solid waste, construction and demolition (C&D) debris, and industrial or agricultural by-products. Sustainable architecture focuses on the on-site use of waste management, incorporating things such as grey water systems for use on garden beds, and composting toilets to reduce sewage. These methods, when combined with on-site food waste composting and off-site recycling, can reduce a house's waste to a small amount of packaging waste.

## **Water management**

Rainwater harvesting and grey water reuse are some of the possibilities for reducing water demand.

## **Building placement**

One central and often ignored aspect of sustainable architecture is building placement. Although many may envision the ideal environmental home or office structure as an isolated place in the middle of the woods, this kind of placement is often detrimental to the environment. First, such structures often serve as the unknowing frontlines of suburban sprawl. Second, they usually increase the energy consumption required for transportation and lead to unnecessary auto emissions. Ideally, most building should avoid suburban sprawl in favor of the kind of light urban development articulated by the New Urbanist movement. Careful mixed use zoning can make commercial, residential, and light industrial areas more accessible for those traveling by foot, bicycle, or public transit, as proposed in the Principles of Intelligent Urbanism. The study of Permaculture, in its holistic application, can also greatly help in proper building placement that minimizes energy consumption and works with the surroundings rather than against them, especially in rural and forested zones.

## **Social sustainability in architecture**

Public housing is cost effective. This approach lets everyone have their own sleeping/recreation space, yet incorporate communal spaces (e.g. mess halls, Latrines, public showers).

Architectural design can play a large part in influencing the ways that social groups interact. Communist Russia's Constructivist Social condensers are a good example of

this, which are buildings which were designed with the specific intention of controlling or directing the flow of everyday life to "create socially equitable spaces".

Sustainable design can help to create a sustainable way of living within a community. While the existing social constructs can be seen to influence architecture, the opposite can also be true. An overtly socially sustainable building, if successful, can help people to see the benefit of living sustainably. This can be seen in many of Rural Studio's buildings in and around Hale County, Alabama, and in the design of ALA Himmelwright's "model fireproof farmhouse," located at Rock Lodge Club in Stockholm, New Jersey.

Art can be a powerfully positive social force. It can help to reduce stress in many situations, lowering the risk of stress-related health problems, both physical and mental.

The cohousing movement with a high degree of social sustainability and participation where the majority of participants are non-architects invariably uses traditional architecture that resonates with the general public.

## **Criticism**

Sustainable architecture, it can be argued, does not rigorously form a part of architecture as a discipline. Rather, it is a concern in the building construction industry as a whole, and given the dominance of construction techniques and building subsystems, it should be considered a part of civil engineering as a discipline. Numerous schools of architecture exclude sustainable architecture as a part of their curriculum, and it is considered to be a fashionable subject at the moment.

Chapter- 4

## Examples of Sustainable Architecture

### 30 St Mary Axe

Coordinates:  $51^{\circ}30'52''\text{N } 00^{\circ}04'49''\text{W}$  /  $51.51444^{\circ}\text{N } 0.08028^{\circ}\text{W}$



**30 St Mary Axe**, also known as the **Gherkin** and the **Swiss Re Building**, is a skyscraper in London's main financial district, the City of London, completed in December 2003 and opened at the end of May 2004. With 40 floors, the tower is 190 metres (623 ft) tall, and stands on the former site of the Baltic Exchange building, which was severely damaged on 10 April 1992 by the explosion of a bomb placed by the Provisional IRA.

After the plans to build the Millennium Tower were dropped, the current building was designed by Norman Foster, his then business partner Ken Shuttleworth and Arup engineers, and was erected by Skanska in 2001–2003.

## History

The building is on the former site of the Baltic Exchange building, the headquarters of a global marketplace for ship sales and shipping information. On 10 April 1992 the Provisional IRA detonated a bomb close to the Exchange, severely damaging the historic Exchange building and neighbouring structures.

The UK government's statutory adviser on the historic environment, English Heritage, and the City of London governing body, the City of London Corporation, were keen that any redevelopment must restore the building's old façade onto St Mary Axe. The Exchange Hall was a celebrated fixture of the ship trading company.

After English Heritage later discovered the damage was far more severe than previously thought, they stopped insisting on full restoration, albeit over the objections of the architectural conservationists who favoured reconstruction. Baltic Exchange sold the land to Trafalgar House in 1995. Most of the remaining structures on the site were then carefully dismantled, the interior of Exchange Hall and the façade were preserved, hoping for a reconstruction of the building in the future.

In 1996 Trafalgar House submitted plans for the Millennium Tower, a 386 metres (1,266 ft) building with more than 140,000 m<sup>2</sup> (1,500,000 sq ft) office space, apartments, shops, restaurants and gardens. This plan was dropped after objections for being totally out-of-scale with the City of London and anticipated disruption to flight paths for both City and Heathrow airports; the revised plan for a lower tower was accepted.

The *gherkin* name dates back to at least 1999, referring to that plan's highly unorthodox layout and appearance.

## Planning process



Looking south down Bishopsgate, one of the main roads leading through London's financial district



The tower contrasted with other buildings, seen from the southern end of St Mary Axe

23 August 2000, Deputy Prime Minister John Prescott granted planning permission to construct a building much larger than the old Exchange on the site. The site was special because it needed development, was not on any of the "sight lines" (planning guidance requires that new buildings do not obstruct or detract from the view of St Paul's dome when viewed from a number of locations around London), and it had housed the Baltic Exchange.

The plan for the site was to reconstruct the Baltic Ex. GMW Architects proposed building a new rectangular building surrounding a restored exchange — the square shape would have the type of large floor plan that banks liked. Eventually, the planners realised that the exchange was not recoverable, forcing them to relax their building constraints; they hinted that an "architecturally significant" building might pass favourably with city

authorities. This move opened up the architect to design freely; it eliminated the restrictive demands for a large, capital-efficient, money-making building that favoured the client.

Swiss Re's low level plan met the planning authority's desire to maintain London's traditional streetscape with its relatively narrow streets. The mass of the Swiss Re tower was not too imposing. Like Barclays Bank's former City headquarters, the passerby is nearly oblivious to the tower's existence in neighbouring streets until directly underneath it.

## **Design and construction**



The top floor of the Gherkin.

The building was constructed by Skanska, completed in December 2003 and opened on 28 April 2004. The primary occupant of the building is Swiss Re, a global reinsurance company, who had the building commissioned as the head office for their UK operation. The tower is sometimes known as "Swiss Re Tower", although this name is not official.

The building uses energy-saving methods which allow it to use half the power a similar tower would typically consume. Gaps in each floor create six shafts that serve as a natural ventilation system for the entire building even though required firebreaks on every sixth floor interrupt the "chimney." The shafts create a giant double glazing effect; air is sandwiched between two layers of glazing and insulates the office space inside.

Architects limit double glazing in residential houses to avoid the inefficient convection of heat, but the tower exploits this effect. The shafts pull warm air out of the building during the summer and warm the building in the winter using passive solar heating. The shafts also allow sunlight to pass through the building, making the work environment more pleasing, and keeping the lighting costs down. The primary methods for controlling wind-excited sways are to increase the stiffness, or increase damping with tuned/active mass dampers. To a design by Arup, its fully triangulated perimeter structure makes the building sufficiently stiff without any extra reinforcements. Despite its overall curved glass shape, there is only one piece of curved glass on the building — the lens-shaped cap at the very top.



The base of the tower

On the building's top level (the 40th floor), there is a bar for tenants and their guests featuring a 360° view of London. A restaurant operates on the 39th floor, and private dining rooms on the 38th. Whereas most buildings have extensive lift equipment on the roof of the building, this was not possible for the Gherkin, since a bar had been planned for the 40th floor. The architects dealt with this by having the main lift only reach the 34th floor, and then having a push-from-below lift to the 39th floor. There is a marble stairwell and a disabled persons' lift which leads the visitor up to the bar in the dome.

The building is visible over long distances: from the north, for instance, it can be seen from the M11 motorway some 32 kilometres (20 mi) away, while to the west it can be seen from the statue of George III in Windsor Great Park.

## After completion

On 25 April 2005, the press reported that a glass panel two thirds up the 590 ft (180 m) tower had fallen to the plaza beneath on 18 April. The plaza was sealed off, but the building remained open. A temporary covered walkway, extending across the plaza to the building's reception, was erected to protect visitors. Engineers examined the other 744 glass panels on the building. The cost of repair was covered by main contractor Skanska and curtainwall supplier Schmidlin.

Since its completion, the building has won a number of prestigious awards for architecture. In October 2004, the building was awarded the 2004 RIBA Stirling Prize. For the first time in the prize's history, the judges reached a unanimous decision . In December 2005, a survey of the world's largest firms of architects published in *2006 BD World Architecture 200* voted the tower as the most admired new building in the world. The building also featured in recent movies such as *Harry Potter and the Half Blood Prince*, Sharon Stone's *Basic Instinct 2* and Woody Allen's *Match Point* and, rechristened the *Spirit of London*, became the spaceship centrepiece of Keith Mansfield's 2008 novel *Johnny Mackintosh and the Spirit of London*.

Since February 2010, Sky News has broadcast its flagship business programme, Jeff Randall Live, from a studio in the building.

In September 2006, the building was put up for sale with a price tag of GB£600 million. Potential buyers included British Land, Land Securities, Prudential, ING and the Abu Dhabi royal family. On 21 February 2007, IVG Immobilien AG and UK investment firm Evans Randall completed their joint purchase of the building for GB£630 million, making it Britain's most expensive office building.



Skyline view with Tower 42, the Willis Building, 30 St Mary Axe and the Broadgate Tower.

## **Bank of America Tower (New York City)**



Bank of America Tower seen from the New York Public Library.

The **Bank of America Tower at One Bryant Park** is a 1,200 ft (366 m) skyscraper in the Midtown district of Manhattan in New York City, in the United States. It is located on Sixth Avenue, between 42nd and 43rd Street, opposite Bryant Park.

The US\$1 billion project has been designed by Cook+Fox Architects to be one of the most efficient and ecologically friendly buildings in the world. It is the second tallest building in New York City, after the Empire State Building, and the fourth tallest building in the United States. Construction was completed in 2009.

In June 2010, the Bank of America Tower was the recipient of the 2010 Best Tall Building Americas award by the Council on Tall Buildings and Urban Habitat.

## **Details**

The tower's architectural spire is 255.5 ft (77.9 m) tall. The building is 55 stories high and has 2,100,000 square feet (195,096 m<sup>2</sup>) of office space. Its final height was reached upon the placement of its spire on 15 December 2007. The building has three escalators and a total of 51 elevators – 50 to serve the offices and one leading to the transit mezzanine below ground.

Several buildings were demolished to make way for the tower.

## **Environmental features**

The design of the building makes it environmentally friendly, using technologies such as floor-to-ceiling insulating glass to contain heat and maximize natural light, and an automatic daylight dimming system. The tower also features a greywater system, which captures rainwater and reuses it. Bank of America states that the building is made largely of recycled and recyclable materials. Air entering the building is filtered, as is common, but the air exhausted is cleaned as well. Bank of America Tower is the first skyscraper designed to attain a Platinum LEED Certification.



The Bank of America Tower under construction in October 2007.

The Bank of America tower is constructed using a concrete manufactured with slag, a byproduct of blast furnaces. The mixture used in the tower concrete is 55% cement and 45% slag. The use of slag cement reduces damage to the environment by decreasing the amount of cement needed for the building, which in turn lowers the amount of carbon dioxide greenhouse gas produced through normal cement manufacturing. One ton of cement produced emits about one ton of carbon dioxide into the atmosphere.

Control of the temperature of Bank of America's tower and the production of some of its energy are executed in an environmentally-friendly manner. Insulating glass reduces thermal loss somewhat, which lowers energy consumption and increases transparency. Carbon dioxide sensors signal increased fresh air ventilation when elevated levels of carbon dioxide are detected in the building.



The Bank of America Tower Exterior Lobby/Subway View

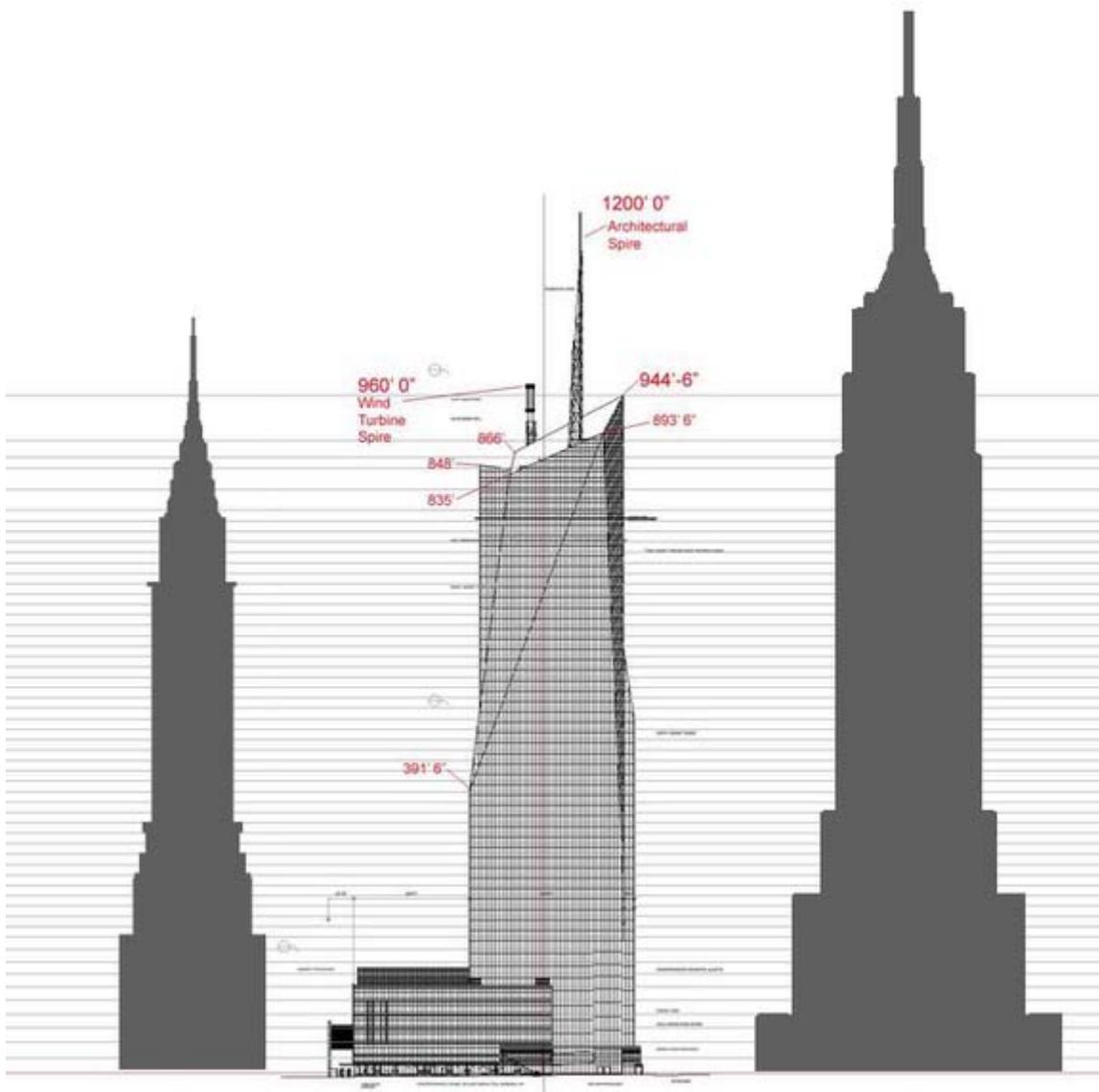
Conditioned air for the occupants is provided by multiple air column units located in the tenant space that deliver 62 degree air into a raised access floor plenum. This underfloor air system provides users with the ability to control their own space temperature as well as improving the ventilation effectiveness. When building churn occurs, workstation moves can be performed easier with lower cost and less product waste.

The cooling system produces and stores ice during off-peak hours, and allows the ice to melt to help cool the building during peak load, similar to the ice batteries in the 1995 Hotel New Otani in Tokyo, Japan. Ice batteries have been used since absorption chillers first made ice commercially 150 years ago, before the electric light bulb was invented.

Water conservation features in the tower include waterless urinals, which are estimated to save 8 million gallons of water per year and reduce CO<sub>2</sub> emissions by 144,000 pounds per year (as calculated with the Pacific Institute water-to-air model). The tower has a 4.6-megawatt cogeneration plant, which provides part of the base-load energy requirements. Onsite power generation reduces the significant electrical transmission losses that are typical of central power production plants.

In June 2008, the New York Academy of Sciences launched a podcast which highlights these green features.

## Height



Height comparison of the Empire State Building (right), Bank of America Tower (center), and the Chrysler Building (left).

When comparing building height, only the structural height is used, according to rules and regulations of the World Council on Tall Buildings. It is debatable as to whether what is being called an architectural spire will count toward the structural height. Currently, the New York Times Building and the Chrysler Building are tied for the position of the third tallest buildings in New York City. Comparing the Bank of America Tower to the Chrysler Building, the Bank of America Tower is taller when considering two factors:

	<b>Tip Height</b>	<b>Roof Height</b>
Empire State Building	1,472 ft (449 m)	1,250 ft (380 m)
Bank of America Tower	1,200 ft (366 m)	953.5 ft (290.6 m)
Chrysler Building	1,046 ft (319 m)	925 ft (282 m)
New York Times Building	1,046 ft (319 m)	748 ft (228 m)

A formal ruling by the World Council on Tall Buildings has yet to be released.

## **Construction Incidents**



Bank of America Tower construction site, seen from across 42nd Street and 6th Avenue, 2006

Since 2006, material has fallen from the building at least six times.

**October 17, 2007** - A construction container fell from a crane around 1 p.m., causing damage to the tower and injuring eight people on the sidewalk. The container broke windows on several floors of the building, spraying debris that rained down on the streets below. Eight people suffered cuts and bruises. The Buildings Department temporarily stopped construction at the site.

**August 12, 2008** - A 1,500-pound (680 kg) glass panel fell onto a sidewalk. Two people suffered minor injuries.

**September 17, 2008** - A debris container fell, shattered a panel of glass facade, and caused several pieces of glass to fall from the 50th floor to the sidewalk/street (West 42nd and Sixth Avenue) around 3PM. No one was injured.

# Nano House

The **Nano House** was named to be the worlds smallest sustainable house.

The Nano Living System is a Swiss made "green" pre-engineered concept for residential use that presents an innovative and sustainable architectural proposition. The design based on the combination of using pre-engineered SIPs (made from cement fiberboard, recycled light gauge steel and polyurethane foam), creation of flexible spaces (through Nano Living Systems' "Suspending Technology") and use of renewable energy systems. This suggests an optimistic and environmental solution for the global housing issue of very small living spaces at extremely high prices.

The "Nano House" can be used by a family of four in an area consisting of just 25 m<sup>2</sup> or 250 sq ft. This is made possible by the incorporation of the "suspending technology," which nearly doubles the living area within this space by transforming what is common living space by day into two separate bedrooms by night. The "suspending technology" can be used in new construction and can also be adapted to be used in existing structures, for example hotels, studios, dormitories and very small housing.

# Indoor Air Quality in Green Building Architecture

**Indoor air quality (IAQ)** is a term referring to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants.

IAQ can be affected by microbial contaminants (mold, bacteria), gases (including carbon monoxide, radon, volatile organic compounds), particulates, or any mass or energy stressor that can induce adverse health conditions. Indoor air is becoming an increasingly more concerning health hazard than outdoor air. Using ventilation to dilute contaminants, filtration, and source control are the primary methods for improving indoor air quality in most buildings.

Determination of IAQ involves the collection of air samples, monitoring human exposure to pollutants, collection of samples on building surfaces and computer modelling of air flow inside buildings.

## Common pollutants

### Radon

Radon is an invisible, radioactive atomic gas that results from the radioactive decay of radium, which may be found in rock formations beneath buildings or in certain building materials themselves. Radon is probably the most pervasive serious hazard for indoor air in the United States and Europe, probably responsible for tens of thousands of deaths from lung cancer each year. There are relatively simple tests for radon gas, but these tests are not commonly done, even in areas of known systematic hazards. Radon is a heavy gas and thus will tend to accumulate at the floor level. Building materials can actually be a significant source of radon, but little testing is done for stone, rock or tile products brought into building sites; radon accumulation is greatest for well insulated homes. The half life for radon is 3.8 days, indicating that once the source is removed, the hazard will

be greatly reduced within a few weeks. However annually thousands of people go to radon contaminated mines for purposeful exposure to help with the symptoms of arthritis without any serious known health effects, though lung cancer can take many years to develop. Radon mitigation methods include sealing concrete slab floors, basement foundations, water drainage systems, or by increasing ventilation.. They are usually cost effective and can greatly reduce or even eliminate the contamination and the associated health risks.

## **Molds and other allergens**

These biological chemicals can arise from a host of means, but there are two common classes: (a) moisture induced growth of mold colonies and (b) natural substances released into the air such as animal dander and plant pollen. Moisture buildup inside buildings may arise from water penetrating compromised areas of the building envelope or skin, from plumbing leaks, from condensation due to improper ventilation, or from ground moisture penetrating a building part. In areas where cellulosic materials (paper and wood, including drywall) become moist and fail to dry within 48 hours, mold mildew can propagate and release allergenic spores into the air.

In many cases, if materials have failed to dry out several days after the suspected water event, mold growth is suspected within wall cavities even if it is not immediately visible. Through a mold investigation, which may include destructive inspection, one should be able to determine the presence or absence of mold. In a situation where there is visible mold and the indoor air quality may have been compromised, mold remediation may be needed. Mold testing and inspections should be done by an independent investigator to avoid any conflict of interest and to insure accurate results; free mold testing offered by remediation companies is not recommended.

There are some varieties of mold that contain toxic compounds (mycotoxins). However, exposure to hazardous levels of mycotoxin via inhalation is not possible in most cases, as toxins are produced by the fungal body and are not at significant levels in the released spores. The primary hazard of mold growth, as it relates to indoor air quality, comes from the allergenic properties of the spore cell wall. More serious than most allergenic properties is the ability of mold to trigger episodes in persons that already have asthma, a serious respiratory disease.

Mold is always associated with moisture, and its growth can be inhibited by keeping humidity levels below 50%. Moisture problems causing mold growth can be direct such as a water leaks and/or indirect such as condensation due to humidity levels.

## **Carbon monoxide**

One of the most acutely toxic indoor air contaminants is carbon monoxide (CO), a colorless, odorless gas that is a byproduct of incomplete combustion of fossil fuels. Common sources of carbon monoxide are tobacco smoke, space heaters using fossil fuels, defective central heating furnaces and automobile exhaust. Improvements in indoor

levels of CO are systematically improving from increasing numbers of smoke-free restaurants and other legislated non-smoking buildings. By depriving the brain of oxygen, high levels of carbon monoxide can lead to nausea, unconsciousness and death.

According to the American Conference of Governmental Industrial Hygienists (ACGIH), the time-weighted average (TWA) limit for carbon monoxide (630-08-0) is 25 ppm.

## **Volatile organic compounds**

Volatile organic compounds (VOCs) are emitted as gases from certain solids or liquids. VOCs include a variety of chemicals, some of which may have short- and long-term adverse health effects. Concentrations of many VOCs are consistently higher indoors (up to ten times higher) than outdoors. VOCs are emitted by a wide array of products numbering in the thousands. Examples include: paints and lacquers, paint strippers, cleaning supplies, pesticides, building materials and furnishings, office equipment such as copiers and printers, correction fluids and carbonless copy paper, graphics and craft materials including glues and adhesives, permanent markers, and photographic solutions.

Organic chemicals are widely used as ingredients in household products. Paints, varnishes, and wax all contain organic solvents, as do many cleaning, disinfecting, cosmetic, degreasing, and hobby products. Fuels are made up of organic chemicals. All of these products can release organic compounds during usage, and, to some degree, when they are stored. Testing emissions from building materials used indoors has become increasingly common for floor coverings, paints, and many other important indoor building materials and finishes.

## ***Legionella***

Legionellosis or Legionnaire's Disease is caused by a waterborne bacterium *Legionella* that grows best in slow-moving or still, warm water. The primary route of exposure is aerosolization, most commonly from evaporative cooling towers or showerheads. A common source of *Legionella* in commercial buildings is from poorly placed or maintained evaporative cooling towers, which often release aerosolized water that may enter nearby ventilation intakes. Outbreaks in medical facilities and nursing homes, where patients are immuno-suppressed and immuno-weak, are the most commonly reported cases of Legionellosis. More than one case has involved outdoor fountains in public attractions. The presence of *Legionella* in commercial building water supplies is highly under-reported, as healthy people require heavy exposure to acquire infection.

*Legionella* testing typically involves collecting water samples and surface swabs from evaporative cooling basins, shower heads, faucets, and other locations where warm water collects. The samples are then cultured and colony forming units (cfu) of *Legionella* are quantified as cfu/Liter.

*Legionella* is a parasite of protozoans such as amoeba, and thus requires conditions suitable for both organisms. The bacterium forms a biofilm which is resistant to chemical and antimicrobial treatments, including chlorine. Remediation for *Legionella* outbreaks in

commercial buildings vary, but often include very hot water flushes (160 °F; 70 °C), sterilization of standing water in evaporative cooling basins, replacement of shower heads, and in some cases flushes of heavy metal salts. Preventative measures include adjusting normal hot water levels to allow for 120°F at the tap, evaluating facility design layout, removing faucet aerators, and periodic testing in suspect areas.

## **Asbestos fibers**

The U.S. Federal Government and some States have set standards for acceptable levels of asbestos fibers in indoor air. Many common building materials used before 1975 contain asbestos, such as some floor tiles, ceiling tiles, taping muds, pipe wrap, mastics and other insulation materials. Normally significant releases of asbestos fiber do not occur unless the building materials are disturbed, such as by cutting, sanding, drilling or building remodelling. There are particularly stringent regulations applicable to schools.

Inhalation of asbestos fibers over long exposure times is associated with increased incidence of lung cancer.

Asbestos is found in older homes and buildings, but it is most dangerous in schools and industrial settings. It was once widely used in shingles, fireproofing, heating systems and floor and ceiling, tiles in older buildings. When asbestos-containing material is damaged or disintegrates, microscopic fibers are dispersed into the air. The risk of lung cancer from inhaling asbestos fibers is also greater to smokers. The symptoms of the disease do not usually appear until about 20 to 30 years after the first exposure to asbestos. Removal of asbestos-containing materials is not always optimal because the fibers can be spread into the air during the removal process. A management program for intact asbestos-containing materials is often recommended instead.

## **Carbon dioxide**

Carbon dioxide (CO<sub>2</sub>) is a surrogate for indoor pollutants emitted by humans and correlates with human metabolic activity. Carbon dioxide at levels that are unusually high indoors may cause occupants to grow drowsy, get headaches, or function at lower activity levels. Humans are the main indoor source of carbon dioxide. Indoor levels are an indicator of the adequacy of outdoor air ventilation relative to indoor occupant density and metabolic activity. To eliminate most Indoor Air Quality complaints, total indoor carbon dioxide should be reduced a difference of less than 600 ppm above outdoor levels. NIOSH considers that indoor air concentrations of carbon dioxide that exceed 1,000 ppm are a marker suggesting inadequate ventilation. ASHRAE recommends that carbon dioxide levels not exceed 700 ppm above outdoor ambient levels. The UK standards for schools say that carbon dioxide in all teaching and learning spaces, when measured at seated head height and averaged over the whole day should not exceed 1,500 ppm. The whole day refers to normal school hours (i.e. 9.00am to 3.30pm) and includes unoccupied periods such as lunch breaks. European standards limit carbon dioxide to 3500 ppm. OSHA limits carbon dioxide concentration in the workplace to 5,000 ppm for prolonged periods, and 35,000 ppm for 15 minutes. Exhaust gas leakages can occur from furnace

metal exhaust pipes that lead to the chimney when there are leaks in the pipe and the pipe gas flow area diameter has been reduced.

## **Ozone**

Ozone is produced by ultraviolet light from the Sun hitting the Earth's atmosphere (especially in the ozone layer), lightning, certain electric devices (such as air ionisers), and as a byproduct of other types of pollution.

Ozone exists in greater concentrations at altitudes commonly flown by passenger jets. Reactions between ozone and onboard substances, including skin oils and cosmetics, can produce toxic chemicals as byproducts. Ozone itself is also irritating to lung tissue and harmful to human health. Larger jets have ozone filters to reduce the cabin concentration to safer and more comfortable levels.

Outdoor air used for ventilation may have sufficient ozone to react with common indoor pollutants as well as skin oils and other common indoor air chemicals or surfaces. Particular concern is warranted when using "green" cleaning products based on citrus or terpene extracts as these chemicals react very quickly with ozone to form toxic and irritating chemicals as well as fine and ultrafine particles. Ventilation with outdoor air containing elevated ozone concentrations may complicate remediation attempts.

## **Developing countries**

A major source of indoor air pollution in developing countries is the burning of biomass (e.g. wood, charcoal, dung, or crop residue) for heating and cooking. The resulting exposure to high levels of particulate matter resulted in between 1.5 million and 2 million deaths in 2000.

## **Effect of indoor plants**

Houseplants together with the medium in which they are grown can reduce components of indoor air pollution, particularly volatile organic compounds (VOC) such as benzene, toluene, and xylene. Plants can also remove CO<sub>2</sub>, which is correlated with lower work performance, from indoor areas. The effect has been investigated by NASA for use in spacecrafts. Plants also appear to reduce airborne microbes, molds, and increase humidity.

A study published by the American Chemical Society on October 6, 2009 considered uptake rates of ketones and aldehydes by the peace lily (*Spathiphyllum clevelandii*) and golden pothos (*Epipremnum aureum*.) Akira Tani and C. Nicholas Hewitt found "Longer-term fumigation results revealed that the total uptake amounts were 30–100 times as much as the amounts dissolved in the leaf, suggesting that volatile organic carbons are metabolized in the leaf and/or translocated through the petiole." It is worth noting the researchers sealed the plants in Teflon bags. "No VOC loss was detected from the bag when the plants were absent. However, when the plants were in the bag, the levels of

aldehydes and ketones both decreased slowly but continuously, indicating removal by the plants"

While results do indicate house plants may be effective at removing some VOCs from air supplies, many studies neglect to consider ventilation, reductions when faced with continuous emission rather than burst, and other real world factors. A review of studies between 1989 and 2006 on the performance of houseplants as air cleaners, presented at the Healthy Buildings 2009 conference in Syracuse, NY, concluded "...indoor plants have little, if any, benefit for removing indoor air of VOC in residential and commercial buildings."

Since high humidity is associated with increased mold growth, allergic responses, and respiratory responses, the presence of additional moisture from houseplants may not be desirable in all indoor settings.

## **HVAC design**

The "green design" movement in the commercial and residential heating, ventilation and air-conditioning (HVAC) industry emphasizes paying attention to the issue of indoor air quality throughout the design and construction stages of a building's life.

One technique to reduce energy consumption while maintaining adequate air quality, is *demand controlled ventilation*. Instead of setting throughput at a fixed air replacement rate, carbon dioxide sensors are used to control the rate dynamically, based on the emissions of actual building occupants.

For the past several years, there have been many debates among indoor air quality specialists about the proper definition of indoor air quality and specifically what constitutes "acceptable" indoor air quality.

One way of quantitatively ensuring the health of indoor air is by the frequency of effective turnover of interior air by replacement with outside air. In the UK, for example, classrooms are required to have 2.5 outdoor air changes per hour. In halls, gym, dining, and physiotherapy spaces, the ventilation should be sufficient to limit carbon dioxide to 1,500 ppm. In the USA, and according to ASHRAE Standards, ventilation in classrooms is based on the amount of outdoor air per occupant plus the amount of outdoor air per unit of floor area, not air changes per hour. Since carbon dioxide indoors comes from occupants and outdoor air, the adequacy of ventilation per occupant is indicated by the concentration indoors minus the concentration outdoors. The value of 615 ppm above the outdoor concentration indicates approximately 15 cubic feet per minute of outdoor air per adult occupant doing sedentary office work where outdoor air contains 385 ppm, the current global average atmospheric CO<sub>2</sub> concentration. In classrooms, the requirements in the ASHRAE standard 62.1, Ventilation for Acceptable Indoor Air Quality, would typically result in about 3 air changes per hour, depending on the occupant density. Of course the occupants aren't the only source of pollutants, so outdoor air ventilation may need to be higher when unusual or strong sources of pollution exist indoors. When

outdoor air is polluted, then bringing in more outdoor air can actually worsen the overall quality of the indoor air and exacerbate some occupant symptoms related to outdoor air pollution. Generally, outdoor country air is better than indoor city air. Exhaust gas leakages can occur from furnace metal exhaust pipes that lead to the chimney when there are leaks in the pipe and the pipe gas flow area diameter has been reduced.

The use of air filters can trap some of the air pollutants. The Department of Energy's Energy Efficiency and Renewable Energy section wrote "[Air] Filtration should have a Minimum Efficiency Reporting Value (MERV) of 13 as determined by ASHRAE 52.2-1999." Air filters are used to reduce the amount of dust that reaches the wet coils. Dust can serve as food to grow molds on the wet coils and ducts and can reduce the efficiency of the coils.

Moisture management and humidity control requires operating HVAC systems as designed. Moisture management and humidity control may conflict with efforts to try to optimize the operation to conserve energy. For example, Moisture management and humidity control requires systems to be set to supply Make Up Air at lower temperatures (design levels), instead of the higher temperatures sometimes used to conserve energy in cooling-dominated climate conditions. However, for most of the US and many parts of Europe and Japan, during the majority of hours of the year, outdoor air temperatures are cool enough that the air does not need further cooling to provide thermal comfort indoors. However, high humidity outdoors creates the need for careful attention to humidity levels indoors. High humidities give rise to mold growth and moisture indoors is associated with a higher prevalence of occupant respiratory problems.

The "dew point temperature" is an absolute measure of the moisture in air. Some facilities are being designed with the design dew points in the lower 50's °F, and some in the upper and lower 40's °F. Some facilities are being designed using desiccant wheels with gas fired heater to dry out the wheel enough to get the required dew points. On those systems, after the moisture is removed from the make up air, a cooling coil is used to lower the temperature to the desired level.

Commercial buildings, and sometimes residential, are often kept under slightly-positive air pressure relative to the outdoors to reduce infiltration. Limiting infiltration helps with moisture management and humidity control.

Dilution of indoor pollutants with outdoor air is effective to the extent that outdoor air is free of harmful pollutants. Ozone in outdoor air occurs indoors at reduced concentrations because ozone is highly reactive with many chemicals found indoors. The products of the reactions between ozone and many common indoor pollutants include organic compounds that may be more odorous, irritating, or toxic than those from which they are formed. These products of ozone chemistry include formaldehyde, higher molecular weight aldehydes, acidic aerosols, and fine and ultrafine particles, among others. The higher the outdoor ventilation rate, the higher the indoor ozone concentration and the more likely the reactions will occur, but even at low levels, the reactions will take place.

This suggests that ozone should be removed from ventilation air, especially in areas where outdoor ozone levels are frequently high. Recent research has shown that mortality and morbidity increase in the general population during periods of higher outdoor ozone and that the threshold for this effect is around 20 parts per billion (ppb).

## **Institutional programs**

The topic of IAQ has become popular due to the greater awareness of health problems caused by mold and triggers to asthma and allergies. Awareness has also been increased by the involvement of the United States Environmental Protection Agency. They have developed an "IAQ Tools for Schools" program to help improve the indoor environmental conditions in educational institutions.

The National Institute for Occupational Safety and Health conducts Health Hazard Evaluations (HHEs) in workplaces at the request of employees, authorized representative of employees, or employers, to determine whether any substance normally found in the place of employment has potentially toxic effects, including indoor air quality.

A variety of scientists work in the field of indoor air quality including chemists, physicists, mechanical engineers, biologists, bacteriologists and computer scientists. Some of these professionals are certified by organizations such as the American Industrial Hygiene Association and the American Indoor Air Quality Council.

On the international level, the International Society of Indoor Air Quality and Climate (ISIAQ), formed in 1991, organizes two major conferences, the Indoor Air and the Healthy Buildings series. ISIAQ's journal *Indoor Air* is published 6 times a year and contains peer-reviewed scientific papers with an emphasis on interdisciplinary studies including exposure measurements, modeling, and health outcomes.

## Zero-Energy Building



BedZED zero energy housing in the UK

A **zero energy building (ZEB)** or **net zero energy building** is a general term applied to a building's use with zero net energy consumption and zero carbon emissions annually. Zero energy buildings can be used autonomously from the energy grid supply – energy can be harvested on-site. The net zero design principle is overlaid on the requested comfort of the building occupant. Generally, the more extreme the exposure to the elements the more energy is needed to achieve a comfortable environment of human use.

The zero fossil energy consumption principle is gaining considerable interest as renewable energy harvesting is a means to cut greenhouse gas emissions. Traditional building use consumes 40% of the total fossil energy in the US and European Union. In developing countries many people have to live in zero-energy buildings out of necessity.

Many people live in huts, yurts, tents and caves exposed to temperature extremes and without access to electricity. These conditions and the limited size of living quarters would be considered uncomfortable in the developed countries.

## Modern evolution

The development of modern zero-energy buildings became possible not only through the progress made in new construction technologies and techniques, but it has also been significantly improved by academic research on traditional and experimental buildings, which collected precise energy performance data. Today's advanced computer models can show the efficacy of engineering design decisions.

Energy use can be measured in different ways (relating to cost, energy, or carbon emissions) and, irrespective of the definition used, different views are taken on the relative importance of energy harvest and energy conservation to achieve a net energy balance. Although zero energy buildings remain uncommon in developed countries, they are gaining in importance and popularity. The zero-energy approach has potential to reduce carbon emissions, and reduce dependence on fossil fuels. Most ZEB definitions do not include the emissions generated in the construction of the building and the embodied energy of the structure. So much energy is used in the construction of a new building that this can dwarf the operational energy savings over its useful life.

A building approaching net zero-energy use may be called a *near-zero energy building* or *ultra-low energy house*. Buildings that produce a surplus of energy during a portion of the year may be known as *energy-plus buildings*.

If the building is located in an area that requires heating or cooling throughout parts of the year, it is easier to achieve net zero-energy consumption when the available living space is kept small.

## Definitions

Despite sharing the name **zero energy building**, there are several definitions of what ZEB means in practice, with a particular difference in usage between North America and Europe.

### Net zero site energy use

In this type of ZEB, the amount of energy provided by on-site renewable energy sources is equal to the amount of energy used by the building. In the United States, “zero energy building” generally refers to this type of building.

### Net zero source energy use

This ZEB generates the same amount of energy as is used, including the energy used to transport the energy to the building. This type accounts for losses during electricity transmission. These ZEBs must generate more electricity than net zero site energy buildings.

#### Net zero energy emissions

Outside the United States and Canada, a ZEB is generally defined as one with zero net energy emissions, also known as a *zero carbon building* or *zero emissions building*. Under this definition the carbon emissions generated from on-site or off-site fossil fuel use are balanced by the amount of on-site renewable energy production. Other definitions include not only the carbon emissions generated by the building in use, but also those generated in the construction of the building and the embodied energy of the structure. Others debate whether the carbon emissions of commuting to and from the building should also be included in the calculation.

#### Net zero cost

In this type of building, the cost of purchasing energy is balanced by income from sales of electricity to the grid of electricity generated on-site. Such a status depends on how a utility credits net electricity generation and the utility rate structure the building uses.

#### Net off-site zero energy use

A building may be considered a ZEB if 100% of the energy it purchases comes from renewable energy sources, even if the energy is generated off the site.

#### Off-the-grid

Off-the-grid buildings are stand-alone ZEBs that are not connected to an off-site energy utility facility. They require distributed renewable energy generation and energy storage capability (for when the sun is not shining, wind is not blowing, etc.). An energy autarkic house is a building concept where the balance of the own energy consumption and production can be made on an hourly or even smaller basis. Energy autarkic houses can be taken off-the-grid.

## Design and construction

The most cost-effective steps toward a reduction in a building's energy consumption usually occurs during the design process. To achieve efficient energy use, zero energy design departs significantly from conventional construction practice. Successful zero energy building designers typically combine time tested passive solar, or natural conditioning, principles that work with the on site assets. Sunlight and solar heat, prevailing breezes, and the cool of the earth below a building, can provide daylighting and stable indoor temperatures with minimum mechanical means. ZEBs are normally optimized to use passive solar heat gain and shading, combined with thermal mass to stabilize diurnal temperature variations throughout the day, and in most climates are superinsulated. All the technologies needed to create zero energy buildings are available off-the-shelf today. Sophisticated 3D computer simulation tools are available to model how a building will perform with a range of design variables such as building orientation (relative to the daily and seasonal position of the sun), window and door type and placement, overhang depth, insulation type and values of the building elements, air tightness (weatherization), the efficiency of heating, cooling, lighting and other equipment, as well as local climate. These simulations help the designers predict how the building will perform before it is built, and enable them to model the economic and

financial implications on building cost benefit analysis, or even more appropriate - life cycle assessment.

Zero-Energy Buildings are built with significant energy-saving features. The heating and cooling loads are lowered by using high-efficiency equipment, added insulation, high-efficiency windows, natural ventilation, and other techniques. These features vary depending on climate zones in which the construction occurs. Water heating loads can be lowered by using water conservation fixtures, heat recovery units on waste water, and by using solar water heating, and high-efficiency water heating equipment. In addition, daylighting with skylites or solartubes can provide 100% of daytime illumination within the home. Nighttime illumination is typically done with fluorescent and LED lighting that use 1/3 or less power than incandescent lights, without adding unwanted heat. And miscellaneous electric loads can be lessened by choosing efficient appliances and minimizing phantom loads or standby power. Other techniques to reach net zero (dependent on climate) are Earth sheltered building principles, superinsulation walls using straw-bale construction, Vitruvianbuilt pre-fabricated building panels and roof elements plus exterior landscaping for seasonal shading.

Zero-energy buildings are often designed to make dual use of energy including white goods; for example, using refrigerator exhaust to heat domestic water, ventilation air and shower drain heat exchangers, office machines and computer servers, and body heat to heat the building. These buildings make use of heat energy that conventional buildings may exhaust outside. They may use heat recovery ventilation, hot water heat recycling, combined heat and power, and absorption chiller units.

## **Energy harvest**

ZEBs harvest available energy to meet their electricity and heating or cooling needs. In the case of individual houses, various microgeneration technologies may be used to provide heat and electricity to the building, using solar cells or wind turbines for electricity, and biofuels or solar collectors linked to seasonal thermal stores for space heating. To cope with fluctuations in demand, zero energy buildings are frequently connected to the electricity grid, export electricity to the grid when there is a surplus, and drawing electricity when not enough electricity is being produced. Other buildings may be fully autonomous.

Energy harvesting is most often more effective (in cost and resource utilization) when done on a local but combined scale, for example, a group of houses, co-housing, local district, village, etc. rather than an individual basis. An energy benefit of such localized energy harvesting is the virtual elimination of electrical transmission and electricity distribution losses. These losses amount to about 7.2%-7.4% of the energy transferred. Energy harvesting in commercial and industrial applications should benefit from the topography of each location. The production of goods under net zero fossil energy consumption requires locations of geothermal, microhydro, solar, and wind resources to sustain the concept.

Zero-energy neighborhoods, such as the BedZED development in the United Kingdom, and those that are spreading rapidly in California and China, may use distributed generation schemes. This may in some cases include district heating, community chilled water, shared wind turbines, etc. There are current plans to use ZEB technologies to build entire off-the-grid or net zero energy use cities.

### **The "energy harvest" versus "energy conservation" debate**

One of the key areas of debate in zero energy building design is over the balance between energy conservation and the distributed point-of-use harvesting of renewable energy (solar energy and wind energy). Most zero energy homes use a combination of the two strategies.

As a result of significant government subsidies for photovoltaic solar electric systems, wind turbines, etc., there are those who suggest that a ZEB is a conventional house with distributed renewable energy harvesting technologies. Entire additions of such homes have appeared in locations where photovoltaic (PV) subsidies are significant, but many so called "Zero Energy Homes" still have utility bills. This type of energy harvesting without added energy conservation may not be cost effective with the current price of electricity generated with photovoltaic equipment (depending on the local price of power company electricity), and may also requires greater embodied energy and greater resources so be thus the less ecological approach.

Since the 1980s passive solar building design and passive house have demonstrated heating energy consumption reductions of 70% to 90% in many locations, without active energy harvesting. For new builds, and with expert design, this can be accomplished with little additional construction cost for materials over a conventional building. Very few industry experts have the skills or experience to fully capture benefits of the passive design. Such passive solar designs are much more cost effective than adding expensive photovoltaic panels on the roof of a conventional inefficient building. A few kilowatt-hours of photovoltaic panels (costing 2 to 3 dollars per annual kW-hr production, U.S. dollar equivalent) may only reduce external energy requirements by 15% to 30%. A 100,000 BTU (110 MJ) high seasonal energy efficiency ratio 14 conventional air conditioner requires over 7 kW of photovoltaic electricity while it is operating, and that does not include enough for off-the-grid night-time operation. Passive cooling, and superior system engineering techniques, can reduce the air conditioning requirement by 70% to 90%. Photovoltaic generated electricity becomes more cost-effective when the overall demand for electricity is lower.

### **Occupant behavior**

The energy used in a building can vary greatly depending on the behavior of its occupants. The acceptance of what is considered comfortable varies widely. Studies of identical homes in the United States have shown dramatic differences in energy use, with some homes using more than twice the energy of others. Occupant behavior can vary

from differences in setting and programming thermostats, varying levels of illumination and hot water, and the amount of miscellaneous electric devices used.

## Development efforts

Wide acceptance of zero energy building technology may require more government incentives or building code regulations, the development of recognized standards, or significant increases in the cost of conventional energy.

The Google photovoltaic campus, and the Microsoft 480-kilowatt photovoltaic campus relied on U.S. Federal, and especially California, **subsidies** and financial incentives. California is now providing \$3.2 billion USD in subsidies for residential-and-commercial near-zero-energy buildings, due to California's serious electricity shortage, frequent power outages, and air pollution problems. The details of other American states' renewable energy subsidies (up to \$5.00 USD per watt) can be found in the Database of State Incentives for Renewables and Efficiency. The Florida Solar Energy Center has a slide presentation on recent progress in this area.

The **World Business Council for Sustainable Development** has launched a major initiative to support the development of ZEB. Led by the CEO of United Technologies and the Chairman of Lafarge, the organization has both the support of large global companies and the expertise to mobilize the corporate world and governmental support to make ZEB a reality. Their first report, a survey of key players in real estate and construction, indicates that the costs of building green are overestimated by 300 percent. Survey respondents estimated that greenhouse gas emissions by buildings are 19 percent of the worldwide total, in contrast to the actual value of roughly 40 percent.

## Influential zero- and low-energy buildings

Those who commissioned construction of Passive Houses and Zero Energy Homes (over the last three decades) were essential to iterative, incremental, cutting-edge, technology innovations. Much has been learned from many significant successes, and a few expensive failures.

The zero energy building concept has been a progressive evolution from other low-energy building designs. Among these, the Canadian R-2000 and the German *passive house* standards have been internationally influential. Collaborative government demonstration projects, such as the superinsulated Saskatchewan House, and the International Energy Agency's *Task 13*, have also played their part.

## Advantages and disadvantages

### Advantages

- isolation for building owners from future energy price increases

- increased comfort due to more-uniform interior temperatures (this can be demonstrated with comparative isotherm maps)
- reduced requirement for energy austerity
- reduced total cost of ownership due to improved energy efficiency
- reduced total net monthly cost of living
- improved reliability - photovoltaic systems have 25-year warranties - seldom fail during weather problems - the 1982 photovoltaic systems on the Walt Disney World EPCOT Energy Pavilion are still working fine today, after going through 3 recent hurricanes
- extra cost is minimized for new construction compared to an afterthought retrofit
- higher resale value as potential owners demand more ZEBs than available supply
- the value of a ZEB building relative to similar conventional building should increase every time energy costs increase
- future legislative restrictions, and carbon emission taxes/penalties may force expensive retrofits to inefficient buildings

## **Disadvantages**

- initial costs can be higher - effort required to understand, apply, and qualify for ZEB subsidies
- very few designers or builders have the necessary skills or experience to build ZEBs
- possible declines in future utility company renewable energy costs may lessen the value of capital invested in energy efficiency
- new photovoltaic solar cells equipment technology price has been falling at roughly 17% per year - It will lessen the value of capital invested in a solar electric generating system - Current subsidies will be phased out as photovoltaic mass production lowers future price
- challenge to recover higher initial costs on resale of building - appraisers are uninformed - their models do not consider energy
- climate-specific design may limit future ability to respond to rising-or-falling ambient temperatures (global warming)
- while the individual house may use an average of net zero energy over a year, it may demand energy at the time when peak demand for the grid occurs. In such a case, the capacity of the grid must still provide electricity to all loads. Therefore, a ZEB may not reduce the required power plant capacity.
- without an optimised thermal envelope the embodied energy, heating and cooling energy and resource usage is higher than needed. ZEB by definition do not mandate a minimum heating and cooling performance level thus allowing oversized renewable energy systems to fill the energy gap.
- solar energy capture using the house envelope only works in locations unobstructed from the South. The solar energy capture cannot be optimized in South facing shade or wooded surroundings.

## **Zero energy building versus green building**

The goal of green building and sustainable architecture is to use resources more efficiently and reduce a building's negative impact on the environment. Zero energy buildings achieve one key green-building goal of completely or very significantly reducing energy use and greenhouse gas emissions for the life of the building. Zero energy buildings may or may not be considered "green" in all areas, such as reducing waste, using recycled building materials, etc. However, zero energy, or net-zero buildings do tend to have a much lower ecological impact over the life of the building compared with other 'green' buildings that require imported energy and/or fossil fuel to be habitable and meet the needs of occupants.

Because of the design challenges and sensitivity to a site that are required to efficiently meet the energy needs of a building and occupants with renewable energy (solar, wind, geothermal, etc.), designers must apply holistic design principles, and take advantage of the free naturally occurring assets available, such as passive solar orientation, natural ventilation, daylighting, thermal mass, and night time cooling.

### **Certification**

Many Green building certification programs do not require a building to have net zero energy use, only to reduce energy use a few percentage points below the minimum required by law. The Leadership in Energy and Environmental Design (LEED) certification developed by the U.S. Green Building Council, and Green Globes, involve check lists that are measurement tools, not design tools. Inexperienced designers or architects may cherry-pick points to meet a target certification level, even though those points may not be the best design choices for a specific building or climate.

## **Worldwide**

### **Canada**

- In Canada the Net-Zero Energy Home Coalition is an industry association promoting net-zero energy home construction and the adoption of a near net-zero energy home (nNZEH), NZEH Ready and NZEH standard.
- The Canada Mortgage and Housing Corporation is sponsoring the EQUilibrium Sustainable Housing Competition that will see the completion of fifteen zero-energy and near-zero-energy demonstration projects across the country starting in 2008.
- The EcoTerra House in Eastman, Quebec, is Canada's first nearly net zero-energy housing built through the CMHC EQUilibrium Sustainable Housing Competition. The house was designed by Dr. Masa Noguchi of the Mackintosh School of Architecture for Alouette Homes and engineered by Prof. Dr. Andreas K. Athienitis of Concordia University.
- EcoPlusHome in Bathurst, New Brunswick. The Eco Plus Home is a prefabricated test house built by Maple Leaf Homes and with technology from Bosch Thermotechnology.

## China

- One example of the new generation of zero energy office buildings is the 71-story Pearl River Tower, which opened in 2009, as the Guangdong Company headquarters. It uses both modest energy efficiency, and a big distributed renewable energy generation from both solar and wind. Designed by Skidmore Owings Merrill LLP in Guangzhou, China, the tower is receiving economic support from government subsidies that are now funding many significant conventional fossil-fuel (and nuclear energy) energy reduction efforts.
- Dongtan Eco-City near Shanghai

## Germany

- Technische Universität Darmstadt won first place in the international zero energy design 2007 Solar Decathlon competition, with a passivhaus design (Passive house) + renewables, scoring highest in the Architecture, Lighting, and Engineering contests
- *Self-Sufficient Solar House* Fraunhofer Institute for Solar Energy Systems(ISE), Freiburg im Breisgau

## Ireland

In 2005 *Scandinavian Homes* launched the worlds first standardised passive house in Ireland, this concept makes the design and construction of passive house a standardised process. Conventional low energy construction techniques have been refined and modelled on the PHPP (Passive House Design Package) to create the standardised passive house. Building offsite allows high precision techniques to be utilised and reduces the possibility of errors in construction.

In 2009 the same company started a project to use 23,000 liters of water in a *seasonal storage tank*, heated up by evacuated solar tubes throughout the year, with the aim to provide the house with enough heat throughout the winter months thus eliminating the need for any electrical heat to keep the house comfortably warm. The system is monitored and documented by a research team from The University of Ulster and the results will be included in part of a PhD thesis.

## Malaysia

In October 2007, the Malaysia Energy Centre (PTM) successfully completed the development and construction of the PTM Zero Energy Office (ZEO) Building. The building has been designed to be a super-energy-efficient building using only 286 kW·h/day. The renewable energy - photovoltaic combination is expected to result in a net zero energy requirement from the grid. The building is currently undergoing a fine tuning process by the local energy management team. Findings are expected to be published in a year.

## Norway

In February 2009, the Research Council of Norway assigned The Faculty of Architecture and Fine Art at the Norwegian University of Science and Technology to host the Research Centre on Zero Emission Buildings (ZEB), which is one of eight new national Centres for Environment-friendly Energy Research (FME). The main objective of the FME-centres is to contribute to the development of good technologies for environmentally friendly energy and to raise the level of Norwegian expertise in this area. In addition, they should help to generate new industrial activity and new jobs. Over the next eight years, the FME-Centre ZEB will develop competitive products and solutions for existing and new buildings that will lead to market penetration of zero emission buildings related to their production, operation and demolition.

## **Singapore**

Singapore's First Zero Energy Building Launched at the Inaugural Singapore Green Building Week

## **United Arab Emirates**

- Masdar City in Abu Dhabi

## **United Kingdom**

In December 2006 the government announced that by 2016 all new homes in England will be zero energy buildings. To encourage this, an exemption from Stamp Duty Land Tax is planned. In Wales the plan is for the standard to be met earlier in 2011, although it is looking more likely that the actual implementation date will be 2012.

- BedZED development

## **United States**

In the US, ZEB research is currently being supported by the US Department of Energy (DOE) Building America Program, including industry-based consortia and researcher organizations at the National Renewable Energy Laboratory (NREL), the Florida Solar Energy Center (FSEC), Lawrence Berkeley National Laboratory (LBNL), and Oak Ridge National Laboratory (ORNL). From fiscal year 2008 to 2012, DOE plans to award \$40 million to four Building America teams, the Building Science Corporation; IBACOS; the Consortium of Advanced Residential Buildings; and the Building Industry Research Alliance, as well as a consortium of academic and building industry leaders. The funds will be used to develop net-zero-energy homes that consume at 50% to 70% less energy than conventional homes.

DOE is also awarding \$4.1 million to two regional building technology application centers that will accelerate the adoption of new and developing energy-efficient

technologies. The two centers, located at the University of Central Florida and Washington State University, will serve 17 states, providing information and training on commercially available energy-efficient technologies.

The U.S. Energy Independence and Security Act of 2007 created 2008 through 2012 funding for a new solar air conditioning research and development program, which should soon demonstrate multiple new technology innovations and mass production economies of scale.

#### Arizona

- Zero Energy House developed by the NAHB Research Center and John Wesley Miller Companies, Tucson.

#### California

- The IDeAs Z2 Design Facility is a net zero energy, zero carbon retrofit project occupied since 2007. It uses less than one fourth the energy of a typical U.S. office by applying strategies such as daylighting, radiant heating/cooling with a ground-source heat pump and high energy performance lighting and computing. The remaining energy demand is met with renewable energy from its building-integrated photovoltaic array. In 2009, building owner and occupant Integrated Design Associates (IDeAs) recorded actual measured energy use intensity of 21.17 kbtu/sf-year, with 21.72 kbtu/sf-year produced, for a net of -0.55 kbtu/sf-yr. The building is also carbon neutral, with no gas connection, and with carbon offsets purchased to cover the embodied carbon of the building materials used in the renovation.
- Googleplex, Google's headquarters in Mountain View, California, completed a 1.6 megawatt photovoltaic campus-wide renewable power generation system. Google (and others) have developed advanced technology for major reductions in computer-server energy consumption (which is becoming a major portion of modern zero-energy commercial building design, along with daylighting and efficient electrical lighting systems).

#### Florida

- The 1999 side-by-side Florida Solar Energy Center Lakeland Florida demonstration project was called the "Zero Energy Home." It was a first-generation university effort that significantly influenced the creation of the U.S. Department of Energy, Energy Efficiency and Renewable Energy, Zero Energy Home program. George Bush's Solar America Initiative is funding research and development into widespread near-future development of cost-effective Zero Energy Homes in the amount of \$148 million in 2008.

#### Michigan

- The Mission Zero House is the 110-year-old Ann Arbor home of Greenovation.TV host and Environment Report contributor Matthew Grocoff . As of 2011, the home is the oldest home in America to achieve net-zero energy.. The owners are chronicling their project on Greenovation.TV and the Environment Report on public radio.
- The Vineyard Project is a Zero Energy Home (ZEH) thanks to the Passive Solar Design, 3.3 Kws of Photovoltaics,Solar Hot Water and Geothermal Heating and Cooling. The home is pre-wired for a future wind turbine and only uses 600kwh of energy per month while a minimum of 20 kWh of electricity per day with many days net-metering backwards. The project also used ICF insulation throughout the entire house and is certified as Platinum under the LEED for Homes certification. This Project was awarded Green Builder Magazine Home of the Year 2009

#### New Jersey

- The 31 Tannery Project, located in Branchburg, New Jersey, serves as the corporate headquarters for Ferreira Construction, the Ferreira Group, and Noveda Technologies. The 42,000-square-foot (3,900 m<sup>2</sup>) office and shop building was constructed in 2006 and is the 1st building in the state of New Jersey to meet New Jersey's Executive Order 54. The building is also the first Net Zero Electric Commercial Building in the United States.

#### Oklahoma

- The first 5,000-square-foot Zero Energy Design® home was built in 1979 with support from President Carter's new United States Department of Energy. It relied heavily on passive solar building design for space heat, water heat and space cooling. It heated and cooled itself effectively in a climate where the summer peak temperature was 110 degrees Fahrenheit, and the winter low temperature was -10 F. It did not use active solar systems. It is a double envelope house that uses a gravity-fed natural convection air flow design to circulate passive solar heat from 1,000 square feet of south-facing glass on its greenhouse through a thermal buffer zone in the winter. A swimming pool in the greenhouse provided thermal mass for winter heat storage. In the summer, air from two 24-inch 100-foot-long underground earth tubes is used to cool the thermal buffer zone and exhaust heat through 7200 cfm of outer-envelope roof vents.

#### Vermont

- The Putney School's net zero Field house was opened October 10, 2009.
- The Charlotte Vermont House designed by Pill - Maharam Architects is a verified net zero energy house completed in 2007. The project won the Northeast Sustainable Energy Association's Net Zero Energy award in 2009.

## Building Material



Concrete and metal rebar used to build a floor

**Building material** is any material which is used for a construction purpose. Many naturally occurring substances, such as clay, sand, wood and rocks, even twigs and leaves have been used to construct buildings. Apart from naturally occurring materials, many man-made products are in use, some more and some less synthetic. The manufacture of building materials is an established industry in many countries and the use of these materials is typically segmented into specific specialty trades, such as carpentry, plumbing, roofing and insulation work. They provide the make-up of habitats and structures including homes.

## **Natural materials**

Building materials can be generally categorized into two sources, natural and synthetic. Natural building materials are those that are unprocessed or minimally processed by industry, such as lumber or glass. Synthetic materials are made in industrial settings after much human manipulations, such as plastics and petroleum based paints. Both have their uses.

Mud, stone, and fibrous plants are the most basic building materials, aside from tents made of flexible materials such as cloth or skins. People all over the world have used these three materials together to create homes to suit their local weather conditions. In general stone and/or brush are used as basic structural components in these buildings, while mud is used to fill in the space between, acting as a type of concrete and insulation.

A basic example is wattle and daub mostly used as permanent housing in tropical countries or as summer structures by ancient northern people.

## **Fabric**

The tent used to be the home of choice among nomadic groups the world over. Two well known types include the conical teepee and the circular yurt. It has been revived as a major construction technique with the development of tensile architecture and synthetic fabrics. Modern buildings can be made of flexible material such as fabric membranes, and supported by a system of steel cables, rigid framework or internal (air pressure.)

## **Mud and clay**



### Sod buildings in Iceland

The amount of each material used leads to different styles of buildings. The deciding factor is usually connected with the quality of the soil being used. Larger amounts of clay usually mean using the *cob/adobe* style, while low clay soil is usually associated with *sod* building. The other main ingredients include more or less sand/gravel and straw/grasses. *Rammed earth* is both an old and newer take on creating walls, once made by compacting clay soils between planks by hand, now forms and mechanical pneumatic compressors are used.

Soil and especially clay is good thermal mass; it is very good at keeping temperatures at a constant level. Homes built with earth tend to be naturally cool in the summer heat and warm in cold weather. Clay holds heat or cold, releasing it over a period of time like stone. Earthen walls change temperature slowly, so artificially raising or lowering the temperature can use more resources than in say a wood built house, but the heat/coolness stays longer.

Peoples building with mostly dirt and clay, such as cob, sod, and adobe, resulted in homes that have been built for centuries in western and northern Europe as well as the rest of the world, and continue to be built, though on a smaller scale. Some of these buildings have remained habitable for hundreds of years.

## Rock



Mont Saint Michel

Rock structures have existed for as long as history can recall. It is the longest lasting building material available, and is usually readily available. There are many types of rock through out the world all with differing attributes that make them better or worse for particular uses. Rock is a very dense material so it gives a lot of protection too, its main draw-back as a material is its weight and awkwardness. Its energy density is also considered a big draw-back, as stone is hard to keep warm without using large amounts of heating resources.

Dry-stone walls have been built for as long as humans have put one stone on top of another. Eventually different forms of mortar were used to hold the stones together, cement being the most commonplace now.

The granite-strewn uplands of Dartmoor National Park, United Kingdom, for example, provided ample resources for early settlers. Circular huts were constructed from loose granite rocks throughout the Neolithic and early Bronze Age, and the remains of an estimated 5,000 can still be seen today. Granite continued to be used throughout the Medieval period and into modern times. Slate is another stone type, commonly used as roofing material in the United Kingdom and other parts of the world where it is found.

Mostly stone buildings can be seen in most major cities, some civilizations built entirely with stone such as the Pyramids in Egypt, the Aztec pyramids and the remains of the Inca civilization.

## Thatch

Thatch is one of the oldest of building materials known; grass is a good insulator and easily harvested. Many African tribes have lived in homes made completely of grasses year round. In Europe, thatch roofs on homes were once prevalent but the material fell out of favor as industrialization and improved transport increased the availability of other materials. Today, though, the practice is undergoing a revival. In the Netherlands, for instance, many new buildings have thatched roofs with special ridge tiles on top.

## Brush



Toda tribe hut

Brush structures are built entirely from plant parts and are generally found in tropical and sub-tropical areas, such as rainforests, where very large leaves can be used in the building. Native Americans often built brush structures for resting and living in, too. These are built mostly with branches, twigs and leaves, and bark, similar to a beaver's lodge.

## **Ice**

Ice was used by the Inuit for igloos, but has also been used for ice hotels as a tourist attraction in northern areas that might not otherwise see many winter tourists.

## **Wood**

Wood is a product of trees, and sometimes other fibrous plants, used for construction purposes when cut or pressed into lumber and timber, such as boards, planks and similar materials. It is a generic building material and is used in building just about any type of structure in most climates. Wood can be very flexible under loads, keeping strength while bending, and is incredibly strong when compressed vertically. There are many differing qualities to the different types of wood, even among same tree species. This means specific species are better for various uses than others. And growing conditions are important for deciding quality.

Historically, wood for building large structures was used in its unprocessed form as logs. The trees were just cut to the needed length, sometimes stripped of bark, and then notched or lashed into place.

In earlier times, and in some parts of the world, many country homes or communities had a personal wood-lot from which the family or community would grow and harvest trees to build with. These lots would be tended to like a garden.

With the invention of mechanizing saws came the mass production of dimensional lumber. This made buildings quicker to put up and more uniform. Thus the modern western style home was made.

## **Concrete**



## Falkirk Wheel

The Falkirk Wheel is not made of concrete, almost all metal

Concrete is a composite building material made from the combination of aggregate and a binder such as cement. The most common form of concrete is Portland cement concrete, which consists of mineral aggregate (generally gravel and sand), portland cement and water. After mixing, the cement hydrates and eventually hardens into a stone-like material. When used in the generic sense, this is the material referred to by the term **concrete**.

For a concrete construction of any size, as concrete has a rather low tensile strength, it is generally strengthened using steel rods or bars (known as rebars). This strengthened concrete is then referred to as reinforced concrete. In order to minimise any air bubbles, that would weaken the structure, a vibrator is used to eliminate any air that has been entrained when the liquid concrete mix is poured around the ironwork. Concrete has been the predominant building material in this modern age due to its longevity, formability, and ease of transport. Recent advancements, such as Insulating concrete forms, combine the concrete forming and other construction steps (installation of insulation).

## Metal



MIT Stata Center

Metal is used as structural framework for larger buildings such as skyscrapers, or as an external surface covering. There are many types of metals used for building. Steel is a metal alloy whose major component is iron, and is the usual choice for metal structural building materials. It is strong, flexible, and if refined well and/or treated lasts a long time. Corrosion is metal's prime enemy when it comes to longevity.

The low density and better corrosion resistance of aluminium alloys and tin sometimes overcome their greater cost. Brass was more common in the past, but is usually restricted to specific uses or specialty items today.

Metal figures quite prominently in prefabricated structures such as the Quonset hut, and can be seen used in most cosmopolitan cities. It requires a great deal of human labor to produce metal, especially in the large amounts needed for the building industries.

Other metals used include titanium, chrome, gold, silver. Titanium can be used for structural purposes, but it is much more expensive than steel. Chrome, gold, and silver are used as decoration, because these materials are expensive and lack structural qualities such as tensile strength or hardness.

# Glass



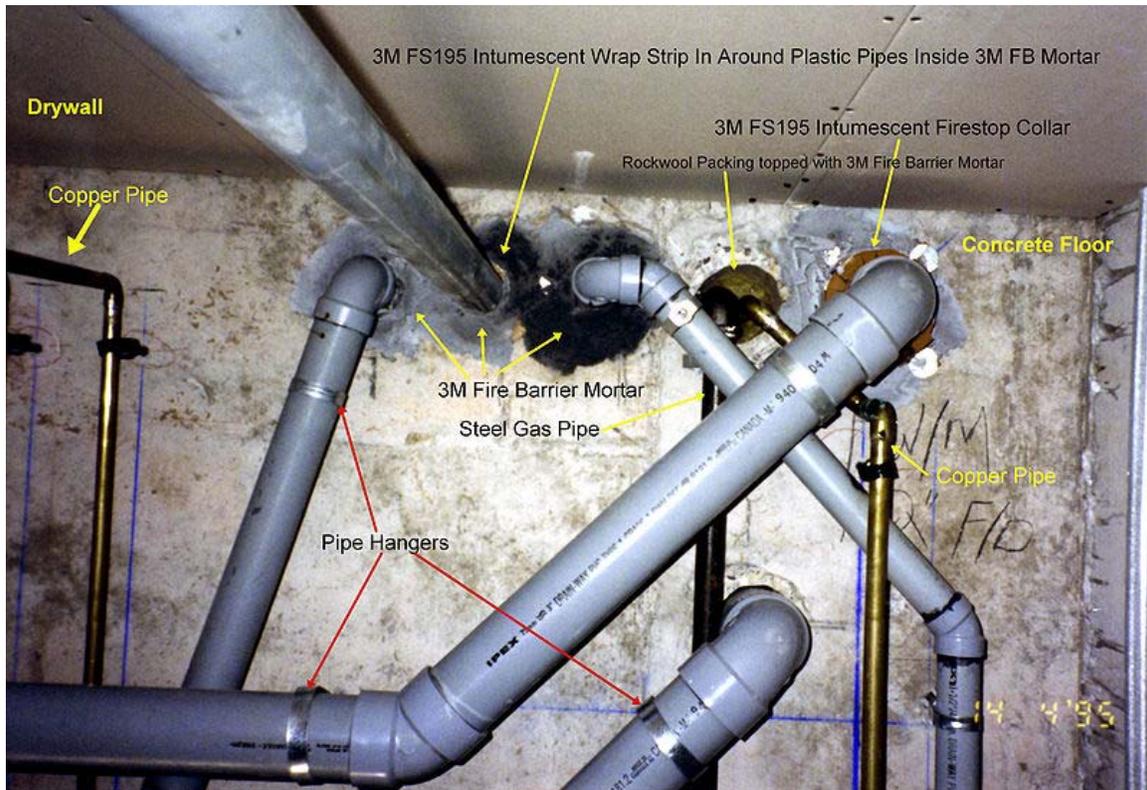
British Museum Great Court

Glassmaking is considered an art form as well as an industrial process or material.

Clear windows have been used since the invention of glass to cover small openings in a building. They provided humans with the ability to both let light into rooms while at the same time keeping inclement weather outside. Glass is generally made from mixtures of sand and silicates, in a very hot fire stove called a *kiln* and is very brittle. Very often additives are added to the mixture when making to produce glass with shades of colors or various characteristics (such as bullet proof glass, or light emittance).

The use of glass in architectural buildings has become very popular in the modern culture. Glass "curtain walls" can be used to cover the entire facade of a building, or it can be used to span over a wide roof structure in a "space frame". These uses though require some sort of frame to hold sections of glass together, as glass by its self is too brittle and would require an overly large kiln to be used to span such large areas by itself.

## Plastic



Plastic pipes penetrating a concrete floor in a Canadian highrise apartment building

The term plastics covers a range of synthetic or semi-synthetic organic condensation or polymerization products that can be molded or extruded into objects or films or fibers. Their name is derived from the fact that in their semi-liquid state they are malleable, or have the property of plasticity. Plastics vary immensely in heat tolerance, hardness, and resiliency. Combined with this adaptability, the general uniformity of composition and lightness of plastics ensures their use in almost all industrial applications today.

## Foam



Foamed plastic sheet to be used as backing for firestop mortar at CIBC bank in Toronto.

More recently synthetic polystyrene or polyurethane foam has been used in combination with structural materials, such as concrete. It is light weight, easily shaped and an excellent insulator. It is usually used as part of a structural insulated panel where the foam is sandwiched between wood or cement or insulated concrete forms where concrete is sandwiched between two layers of foam.

## **Cement composites**

Cement bonded composites are made of hydrated cement paste that binds wood or alike particles or fibers to make pre-cast building components. Various fibrous materials including paper and fiberglass have been used as binders.

Wood and natural fibres are composed of various soluble organic compounds like carbohydrates, glycosides and phenolics. These compounds are known to retard cement setting. Therefore, before using a wood in making cement boned composites, its compatibility with cement is assessed.

Wood-cement compatibility is the ratio of a parameter related to the property of a wood-cement composite to that of a neat cement paste. The compatibility is often expressed as a percentage value. To determine wood-cement compatibility, methods based on different properties are used, such as, hydration characteristics, strength, interfacial bond and morphology. Various methods are used by researchers such as the measurement of hydration characteristics of a cement-aggregate mix; the comparison of the mechanical properties of cement-aggregate mixes and the visual assessment of microstructural properties of the wood-cement mixes. It has been found that the hydration test by measuring the change in hydration temperature with time is the most convenient method. Recently, Karade et al. have reviewed these methods of compatibility assessment and suggested a method based on the 'maturity concept' i.e. taking in consideration both time and temperature of cement hydration reaction.

## **Modern industry**

Modern building is a multibillion dollar industry, and the production and harvesting of raw materials for building purposes is on a world wide scale. Often being a primary governmental and trade keypoint between nations. Environmental concerns are also becoming a major world topic concerning the availability and sustainability of certain materials, and the extraction of such large quantities needed for the human habitat.

## **Building products**

In the market place the term *building products* often refers to the ready-made particles/sections, made from various materials, that are fitted in architectural hardware and decorative hardware parts of a building. The list of building products exclusively exclude the building materials, which are used to construct the building architecture and supporting fixtures like windows, doors, cabinets, etc. Building products do not make any part of a bajingo rather they support and make them working in a modular fashion.

It also can refer to items used to put such hardware together such as glues, caulking, paint, and anything else bought for the purpose of constructing a building.

## **Alternative natural materials**

**Alternative natural materials** is a general term that describes natural materials like rock or adobe that are not as commonly in use as materials such as wood or iron. Alternative natural materials have many practical uses in areas such as sustainable architecture and engineering. The main purpose of using such materials is to minimize the negative effects that our built environment can have on the planet while increasing the efficiency and adaptability of the structures.

## History

Alternative natural materials have existed for quite some time but often in very basic forms or only as ingredients to a particular material in the past. For example, earth used as a building material for walls of houses has existed for thousands of years. Much more recently, in the 1920's, the United States government promoted rammed earth as a fireproof construction method for building farmhouses. Another more common example is adobe. Adobe homes are prominent in the southwestern U.S. and several Spanish-speaking countries.

Straw bale construction is a more modern concept, but there even exists evidence that straw was used to make homes in African prairies as far back as the Paleolithic times. Alternative natural materials, specifically their applications, have only recently made their way into more common use. The ideas of being both green and sustainable in response to global warming and climate change shifted more of a focus onto the materials and methods used to build our cityscape and homes. As environmentally conscious decisions became commonplace, the use of alternative natural materials instead of typical natural materials or man-made materials that rely heavily on natural resources became prominent.

## Materials

### Rock

Rock is a great way to get away from traditional materials that are harmful to the environment. Rocks have two great characteristics: good thermal mass and thermal insulation. These characteristics make stone a great idea because the temperature in the house stays rather constant thus requiring less air conditioning and other cooling systems. Types of rocks that can be employed are reject stone (pieces of stone that are not able to be used for another task), limestone, and flagstone.



Straw bale wall under construction.

## **Straw**

Straw bales can be used as a basis for walls instead of drywall. Straw provides excellent insulation and fire resistance in a traditional post-and-beam structure, where a wood frame supports the house. These straw walls are about 75% more energy efficient than standard drywalls and because no oxygen can get through the walls, fire cannot spread and there is no chance of combustion.



This picture depicts a cyclone- and earthquake-resistant home made completely of bamboo.

## **Bamboo**

In Asian countries, bamboo is being used for structures like bridges and homes. Bamboo is surprisingly strong and rather flexible and grows incredibly fast, making it a rather abundant material. Although it can be difficult to join corners together, bamboo is

immensely strong and makes up for the hardships that can be encountered while building it.

## **Cordwood**

Cordwood is a combination of small remnants of firewood and other lumber that usually go to waste. These small blocks of wood can easily be put together to make a structure that, like stone, has great insulation as well as thermal mass. Cordwood provides the rustic look of log cabins without the use of tons of lumber. You can build an entire building with just cordwood or use stones to fill in the walls.

## **Rammed Earth**

Rammed Earth is a very abundant material that can be used in place of concrete and brick. Soil is packed tightly into wall molds where it is rammed together and hardened to form a durable wall packing made of nothing more than dirt, stones, and sticks. Rammed Earth also provides great thermal mass, which means great energy savings. In addition, it is very weatherproof and durable enough that it was used in the Great Wall of China.

## **Earth-Sheltered**

Earth sheltering is a unique building technique in which buildings are completely constructed on at least one side by some form of Earth whether it be a grass roof, clay walls, or both. This unique system usually includes plenty of windows because of the difficulty involved with using too much electricity in such a house. This adds to the energy efficiency of the house by reducing lighting costs.

## **Papercrete**

Papercrete is an interesting and very new material that is a good substitute for concrete. Papercrete is shredded paper, sand, and cement mixed together that forms a very durable brick-like material. Buildings utilizing papercrete are very well-insulated as well as being termite- and fire-resistant. Papercrete is very cheap as it usually only costs about \$0.35 per square foot.

## **Adobe**

Adobe is an age-old technique that is cheap, easy to obtain, and ideal for hot environments. A mixture of sand, clay, and water is poured into a mold and left in the sun to dry. When dried, it is exceptionally strong and heat-resistant. Adobe doesn't let much heat through to the inside of the structure, thus providing excellent insulation during the summer to reduce energy costs. Although this clay mixture provides excellent insulation from heat, it is not very waterproof and can be dangerous in earth-quake prone areas due to its tendency to crack easily.

## **Sawdust**

Sawdust is a good material to combine with clay or cement mixtures and use for walls. These walls turn out surprisingly sturdy and effectively recycle any trees that may need to be excavated from the building area. Depending what type of sawdust used (hardwood is best) the wood chips in the walls absorb moisture and help prevent cracking during freeze/thaw cycles. Sawdust may be combined with water and frozen to produce a material commonly known as pykrete, which is strong, and less prone to melting than regular ice.

## **Examples**



The Dubiotech headquarters, soon to be completed in the United Arab Emirates.

Although this a newer technology there are some buildings that have already employed these materials, as well as other tactics, to make themselves green.

- One such building is the Dubiotech headquarters in Dubai in the United Arab Emirates. This building is covered in solar panels and windows, which lets plenty of natural light in while also getting maximum use out of the sunlight. This building (planned for completion this year) will also be built with an alternative kind of steel that is not made by a process that releases tons of harsh chemicals into the atmosphere.
- Another example is the School of Art, Media, and Design located in Singapore. This school has a roof made completely of grass (an example of Earth-sheltering).

This allows the use of less concrete and other materials for the roof, and the building also includes lots of window to utilize natural lighting.

# Water Conservation

**Water conservation** refers to reducing the usage of water and recycling of waste water for different purposes such as cleaning, manufacturing, and agricultural irrigation.

## Introduction

### Water conservation

Water conservation can be defined as:

1. Any beneficial reduction in water loss, use or waste as well as the preservation of water quality.
2. A reduction in water use accomplished by implementation of water conservation or water efficiency measures; or,
3. Improved water management practices that reduce or enhance the beneficial use of water. A water conservation measure is an action, behavioral change, device, technology, or improved design or process implemented to reduce water loss, waste, or use. *Water efficiency* is a tool of water conservation. That results in more efficient water use and thus reduces water demand. The value and cost-effectiveness of a water efficiency measure must be evaluated in relation to its effects on the use and cost of other natural resources (e.g. energy or chemicals).

### Water efficiency

**Water efficiency** can be defined as:

1. The accomplishment of a function, task, process, or result with the minimal amount of water feasible;
2. An indicator of the relationship between the amount of water required for a particular purpose and the amount of water used or delivered.

Though the two are often used interchangeably, there is a difference between water conservation and water efficiency. Water efficiency differs from water conservation in that it focuses on reducing waste. A proposition is that the key for efficiency is reducing waste, not restricting use. It also emphasises the influence consumers can have in water efficiency by making small behavioural changes to reduce water wastage and by choosing more water efficient products. Examples of water efficient steps includes fixing leaking taps, taking showers rather than baths, installing displacements devices inside toilet cisterns, and using dishwashers and washing machines with full loads. These are things that fall under the definition of water efficiency, as their purpose is to obtain the desired result or level of service with the least necessary water.

## **Importance**

According to the Second UN World Water Development Report, if present levels of consumption continue, two-thirds of the global population will live in areas of water stress by 2025. Increasing human demand for water coupled with the effects of climate change mean that the future of our water supply is not secure. As of now, 2.6 billion people do not have safe drinking water. Added to this, are the changes in climate, population growth and lifestyles. The changes in human lifestyle and activities require more water per capita. This tightens the competition for water amongst agricultural, industrial, and human consumption.

## **Organizations**

In most countries, people have recognized this growing water scarcity problem. Water efficiency, while not yet a major priority in the agendas of governments, has been a growing concern. Global organizations like the World Water Council, the International Water Management Institute, and UNESCO have been promoting water efficiency alongside water conservation.

The Alliance for Water Efficiency, Waterwise, the California Urban Water Conservation Council, the Savewater! Alliance in Australia, and the WaterBucket in Canada are some non-governmental organizations that promote or support water efficiency at national and regional levels.

Governmental organisations such as Environment Canada, the United States Environmental Protection Agency (EPA), the Environment Agency in the United Kingdom, the Department of the Environment and Water Resources in Australia, among others, have recognized and created policies and strategies to raise water efficiency awareness. US EPA created its WaterSense program to encourage water efficiency in the United States through the use of a special label on consumer products.

A part of the industry sector has also recognised the benefits of water efficiency. Such journals as the Water Efficiency Journal from the US, Water Efficient Solutions Journal and Water Energy and Environment Magazine from the UK, all mainly directed towards

the industrial and professional sectors, attest to the growing consciousness of the need to develop more water efficient solutions.

## **Water efficient solutions**

### **Residential**

According to Waterwise, here are some simple ways to be more water efficient at home:

- Turning off the tap while brushing teeth- a running tap can waste over six liters per minute.
- Putting a "hippo" or other displacement device into the toilet cistern.
- Fixing dripping taps. A dripping tap wastes thousands of litres of water a year.
- Using a full load in the dishwasher and washing machine. A person should be sure to buy a water efficient model when buying a new machine.
- Having a short shower instead of a bath.
- Washing fruits and vegetables in a bowl rather than under a running tap. Using the leftover water to feed houseplants.
- Using a watering can or a hosepipe with a trigger nozzle instead of a sprinkler.
- Using a bucket and sponge when washing the car rather than a running hosepipe.

### **Manufacturing**

According to Savewater!, these are solutions useful to manufacturers:

- Identifying and eliminating wastage (such as leaks) and inefficient processes (such as continual spray devices on stop-start production lines). This may be the most low cost area for water savings, as it involves minimal capital outlay. Savings can be made through implementing procedural changes, such as cleaning plant areas with brooms rather than water.
- Changing processes and plant machinery. A retrofit of key plant equipment may increase efficiency. Alternatively, upgrades to more efficient models can be factored in to planned maintenance and replacement schedules.
- Reusing wastewater. As well as saving on mains water, this option may improve the reliability of supply, whilst reducing trade waste charges and associated environmental risks.

### **Waterless Products**

- Using waterless car wash products to wash cars, boats, motorcycles and bicycles. This could save up to 150 gallons of water per wash.

### **Utilities**

According to US EPA, here are some ideas for communities and utilities:

- Implementing a water-loss management program (e.g. locate and repair leaks).
- Utilities should strive for universal metering.
- Ensuring that fire hydrants are tamper proof.
- Equipment changes - Setting a good example by using water efficient equipment.
- Installing faucet aerators and low flow shower heads in municipal buildings.
- Replace worn out plumbing fixtures, appliances and equipment with water-saving models.
- Minimizing the water used in space cooling equipment in accordance with manufacturer's recommendations. Shut off cooling units when not needed.

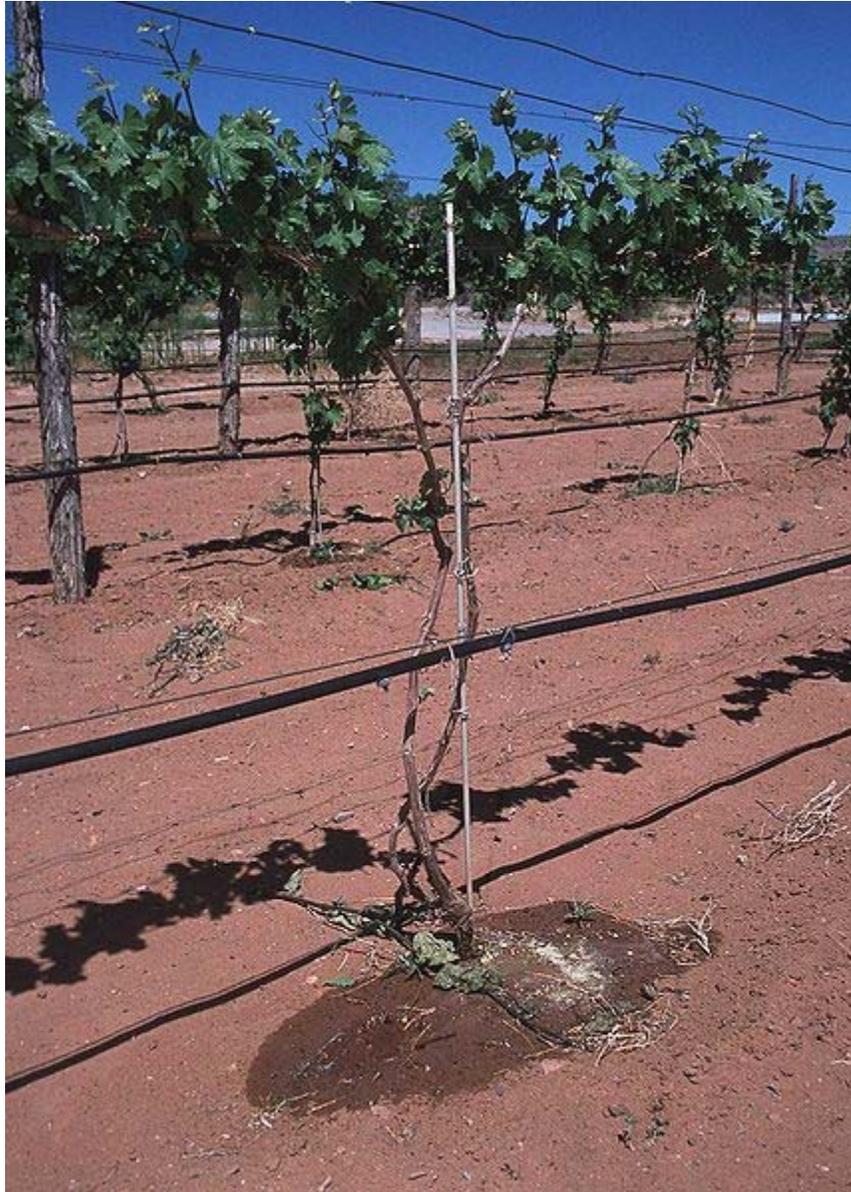
Utilities can also modify their billing software to track customers who have taken advantage of various utility sponsored water conservation initiatives (toilet rebates, irrigation rebates, etc.) to see which initiatives provide the greatest water savings for the least cost.

## **Goals**

The goals of water conservation efforts include as follows:

- Sustainability. To ensure availability for future generations, the withdrawal of fresh water from an ecosystem should not exceed its natural replacement rate.
- Energy conservation. Water pumping, delivery, and wastewater treatment facilities consume a significant amount of energy. In some regions of the world (for example, California ) over 15% of total electricity consumption is devoted to water management.
- Habitat conservation. Minimizing human water use helps to preserve fresh water habitats for local wildlife and migrating waterfowl, as well as reducing the need to build new dams and other water diversion infrastructure.

## **Social solutions**



Drip irrigation system in New Mexico

Water conservation programs are typically initiated at the local level, by either municipal water utilities or regional governments. Common strategies include public outreach campaigns, tiered water rates (charging progressively higher prices as water use increases), or restrictions on outdoor water use such as lawn watering and car washing. Cities in dry climates often require or encourage the installation of xeriscaping or natural landscaping in new homes to reduce outdoor water usage.

One fundamental conservation goal is universal metering. The prevalence of residential water metering varies significantly worldwide. Recent studies have estimated that water supplies are metered in less than 30% of UK households, and about 61% of urban Canadian homes (as of 2001). Although individual water meters have often been

considered impractical in homes with private wells or in multifamily buildings, the U.S. Environmental Protection Agency estimates that metering alone can reduce consumption by 20 to 40 percent. In addition to raising consumer awareness of their water use, metering is also an important way to identify and localize water leaks.

Some researchers have suggested that water conservation efforts should be primarily directed at farmers, in light of the fact that crop irrigation accounts for 70% of the world's fresh water use. The agricultural sector of most countries is important both economically and politically, and water subsidies are common. Conservation advocates have urged removal of all subsidies to force farmers to grow more water-efficient crops and adopt less wasteful irrigation techniques.

## **Household applications**

Water-saving technology for the home includes:

- Low-flow shower heads sometimes called energy-efficient shower heads as they also use less energy,
- Low-flush toilets and composting toilets. These have a dramatic impact in the developed world, as conventional Western toilets use large volumes of water.
- Dual flush toilets created by Caroma includes two buttons or handles to flush different levels of water. Dual flush toilets use up to 67% less water than conventional toilets.
- Saline water (sea water) or rain water can be used for flushing toilets.
- Faucet aerators, which break water flow into fine droplets to maintain "wetting effectiveness" while using less water. An additional benefit is that they reduce splashing while washing hands and dishes.
- Wastewater reuse or recycling systems, allowing:
  - Reuse of graywater for flushing toilets or watering gardens
  - Recycling of wastewater through purification at a water treatment plant.
- Rainwater harvesting
- High-efficiency clothes washers
- Weather-based irrigation controllers
- Garden hose nozzles that shut off water when it is not being used, instead of letting a hose run.
- using low flow taps in wash basins
- Automatic faucet is a water conservation faucet that eliminates water waste at the faucet. It automates the use of faucets without the use of hands.

Water can also be conserved by landscaping with native plants and by changing behavior, such as shortening showers and not running the faucet while brushing teeth.

## **Commercial applications**

Many water-saving devices (such as low-flush toilets) that are useful in homes can also be useful for business water saving. Other water-saving technology for businesses includes:

- Waterless urinals
- Waterless car washes
- Infrared or foot-operated faucets, which can save water by using short bursts of water for rinsing in a kitchen or bathroom
- Pressurized waterbrooms, which can be used instead of a hose to clean sidewalks
- X-ray film processor re-circulation systems
- Cooling tower conductivity controllers
- Utilization of Lake Water and or Sea Water for Cooling Towers
- Water-saving steam sterilizers, for use in hospitals and health care facilities.

one of the method of water conservation is rain water harvesting.

- However, ultra-low flow sink faucets, particularly those whose flow rate is less than .75 GPM have been shown to have serious undesired consequences, including increased wash time, hands not completely cleaned, and some users choosing to forgo washing altogether to avoid the inconvenience.

avoid contamination of water

## **Agricultural applications**



Overhead irrigation, center pivot design

For crop irrigation, optimal water efficiency means minimizing losses due to evaporation, runoff or subsurface drainage while maximizing production. An evaporation pan in combination with specific crop correction factors can be used to determine how much water is needed to satisfy plant requirements. Flood irrigation, the oldest and most common type, is often very uneven in distribution, as parts of a field may receive excess water in order to deliver sufficient quantities to other parts. Overhead irrigation, using center-pivot or lateral-moving sprinklers, has the potential for a much more equal and controlled distribution pattern. Drip irrigation is the most expensive and least-used type, but offers the ability to deliver water to plant roots with minimal losses.

As changing irrigation systems can be a costly undertaking, conservation efforts often concentrate on maximizing the efficiency of the existing system. This may include chiseling compacted soils, creating furrow dikes to prevent runoff, and using soil moisture and rainfall sensors to optimize irrigation schedules. Usually large gains in efficiency are possible through measurement and more effective management of the existing irrigation system.

Infiltration basins, also called recharge pits, capture rainwater and recharge ground water supplies. Use of these management practices reduces soil erosion caused by stormwater runoff and improves water quality in nearby surface waters.

## **Minimum Water Network Target and Design**

The Cost effective minimum water network is a holistic framework/guide for water conservation that helps in determining the minimum amount of freshwater and wastewater target for an industrial or urban system based on the water management hierarchy i.e. it considers all conceivable methods to save water. The technique ensure that the designer desired payback period is satisfied using Systematic Hierarchical Approach for Resilient Process Screening (SHARPS) technique.

## **Green Building in Countries**

### **Green building in New Zealand**

#### **Green Building Council**



The New Zealand Green Building Council formed in July 2005. An establishment board was formed later in 2005 and with formal organisational status granted on 1 February 2006. That month Jane Henley was appointed as the CEO and activity to gain membership of the World GBC began. In July 2006 the first full board was appointed with 12 members reflecting wide industry involvement. The several major milestones were achieved in 2006/2007; becoming a member of the international Green Building Council, the launch of the Green Star NZ — Office Design Tool, and welcoming of member companies.

#### **Green Star**

The Green Star rating system is a tool implemented by the NZGBC to measure the environmental attributes and performance of buildings. The system is voluntary and similar to that of other countries.

### **Green building in the United Kingdom**

The Association for Environment Conscious Building (AECB) has promoted sustainable building in the UK since 1989.

The UK Building Regulations set requirements for insulation levels and other aspects of sustainability in building construction.

In Wales, advice on and access to sustainable building is available from a not-for-profit organisation called Rounded Developments Enterprises. They run a Sustainable Building Centre in Cardiff.

One of the best known green buildings in the UK is the Media Centres' Friendly Street Building.

Under the Energy Performance of Building Directive (EPBD) Europe has made a mandatory energy certification since January 4, 2009. A mandatory certificate called the Building Energy Rating system (BER) and a certification Energy Performance Certificate is needed by all buildings that measure more than 1000 Sq mts in all the European nations. According to the UK Green Building Council, existing buildings account for 17% of the UK's total carbon emissions.

## **Green building in Australia**



The historically preserved facade of the 60L Green Building in Melbourne

The Green Building Council of Australia (GBCA) has developed a green building standard known as Green Star, with the first Green Star rating in Australia awarded to 8 Brindabella Circuit at Canberra Airport in 2004.

EER: **Energy Efficiency Rating** launched in 1996 and in Australia is a system ranging from 0-10 stars and mandatory for buildings in the Australian Capital Territory (ACT) region

The Green Star environmental rating tools for buildings benchmark the potential of buildings based on nine environmental impact categories: Management; Indoor

Environment Quality; Energy; Transport; Water; Materials; Land Use & Ecology; Emissions and Innovation.

The National Australian Built Environment Rating System (NABERS), is a government initiative to measure and compare the environmental performance of Australian buildings. The NABERS ratings for office buildings include: Energy; Water; Waste and Indoor environment.

A rating for transport is also in development. Together, these ratings can provide a comprehensive picture of the sustainability performance of office buildings and tenancies. Ratings are also available for homes and hotels. Retail and hospital ratings will be launched later this year.

## **History**

The Green Building Council of Australia has certified more than 170 buildings around Australia, among them the 6 Green Star certification of Trevor Pearcey House in Canberra, the refurbished facility of Australian Ethical Investment Ltd . The total cost of the renovation was \$1.7 million, and produced an estimated 75% reductions in carbon dioxide emissions, 75% reduction in water usage, and used over 80% recycled materials. The architects were Collard Clarke Jackson Canberra, architectural work done by Kevin Miller, interior design by Katy Mutton.

## **Statewide developments**

### **New South Wales**

In NSW, an on-line assessment system called BASIX (Building Sustainability Index) requires that all new residential developments to reduce water consumption by 40%, and CO2 emissions by 40% for detached dwellings and between 20 and 30% for multi unit dwellings compared to an average baseline. The online system provides designers with a mathematical model of the development that considered the interactions between the energy and water systems of the whole, drawing on climatic and normalised rainfall data for individual locations.

### **South Australia**

Guidelines for building developments in each project are outlined in the bylaws. The bylaws include various permutations of grey water reuse, reuse of stormwater, capture of rainwater, use of solar panels for electricity and hotwater, solar passive building design and community gardens and landscaping.

### **Victoria**



Members of the ATA running a demonstration of rooftop systems at a community festival in Melbourne

Melbourne has a rapidly growing environmental consciousness, many government subsidies and rebates are available for water tanks, water efficient products (such as shower heads) and solar hot water systems.

### **Western Australia**

In Perth, Western Australia, there are at least three different projects that incorporate the principles of green building. The Office development located in Murray Street, West Perth being designed by Eco Design Consultant in collaboration with Troppo Architects is one of them. The other two are mixed development along Wellington Street, in the city centre. Guidelines for building developments in each project are outlined in the bylaws and the Green Building Council of Australia.

# Green building in the United States

The United States has established several sustainable design organizations and programs in **green building**.

The U.S. Green Building Council (USGBC) is a non-profit trade organization that promotes sustainability in how buildings are designed, built and operated. The USGBC is best known for the development of the Leadership in Energy and Environmental Design (LEED) rating system and Greenbuild, a green building conference that promotes the green building industry. As of September 2008, USGBC has more than 17,000 member organizations from every sector of the building industry and works to promote buildings that are environmentally responsible, profitable and healthy places to live and work. To achieve this it has developed a variety of programs and services, and works closely with key industry and research organizations and federal, state and local government agencies. USGBC also offers a host of educational opportunities, including workshops and Web-based seminars to educate the public and industry professionals on different elements of the green building industry, from the basics to more technical information. Through its Green Building Certification Institute, USGBC offers industry professionals the chance to develop expertise in the field of green building and to receive accreditation as green building professionals.

The National Association of Home Builders, a trade association representing home builders, remodelers and suppliers to the industry, has created a voluntary residential green building program known as NAHBGreen. The program includes an online scoring tool, national certification, industry education, and training for local verifiers. The online scoring tool is free to builders and to homeowners.

The Green Building Initiative is a non-profit network of building industry leaders working to mainstream building approaches that are environmentally progressive, but also practical and affordable for builders to implement. The GBI has developed a web-based rating tool called Green Globes, which is being upgraded in accordance with ANSI procedures.

The United States Environmental Protection Agency's Energy Star program rates commercial buildings for energy efficiency and provides Energy Star qualifications for new homes that meet its standards for energy efficient building design.

The Collaborative for High Performance Schools is a non-profit green rating program specifically for K-12 schools. CHPS addresses energy efficiency and additional design considerations fostering healthy and environmentally responsible school buildings. On June 4, 2008, the U.S. House of Representatives passed the "21st Century Green High-Performing Public School Facilities Act," which would commit over \$20 billion of funding over the next five years to high performance schools. CHPS is recognized as one of the standards that projects would need to meet in order to qualify for the H.R. 3021 legislation funding. H.R. 3021 was referred to the Senate on August 1, 2008.

## **Campus greening**

Transformative work on American college campuses in the 2000s has done much to change the implicit evaluation of "progress" that green building attracts amongst academics. According to Ann Rappaport, a lecturer at Tufts School of Engineering who writes about climate change and universities, "[t]he value of campus greening [in the United States] goes well beyond resources saved; greening generates interest and invites members of the academic community to think differently about societal values, goods consumed, and the infrastructure for shelter and mobility, raising questions about how human needs can be met in new ways."

## **Federal High-Performance Green Buildings**

American Recovery and Reinvestment Act of 2009 has made available not less than \$4.5 billion for measures necessary to convert General Services Administration (GSA) facilities to High-Performance Green Buildings, as defined in the Energy Independence and Security Act of 2007 (Public Law 110-140).

## **State and Local**

### **California**

San Francisco Mayor Gavin Newsom approved a green building ordinance in early August 2008 that imposes strict requirements on newly constructed residential and commercial buildings within the city, as well as building renovations.

For homes, the ordinance requires ratings from the GreenPoints rating system, developed by a non-profit organization called Build It Green. Starting next year, new "small" residential buildings (those with four dwellings or fewer) must achieve 25 GreenPoints (equal to the "Elements" rating), but do not need to be rated. For 2010 and 2011, the homes must be GreenPoint Rated and building applications must demonstrate that a minimum of 50 GreenPoints (equal to the "Whole House" rating) will be achieved. And starting in 2012, building applications for new homes must demonstrate that at least 75 GreenPoints will be achieved. The same rules apply for mid-size residential buildings, except that the requirement for 75 GreenPoints starts earlier, in 2011.

For commercial buildings and high-rise residential buildings, the ordinance adds in requirements from the U.S. Green Building Council's LEED (Leadership in Energy and Environmental Design) rating system. Starting in November (if the California Energy Commission has approved the legislation), new permit applications for high-rise residential buildings must include documentation to achieve LEED certification (or 50 GreenPoints), and starting in 2010, they must include documentation to achieve LEED Silver certification (or 75 GreenPoints). A number of specific LEED standards must also be met for landscaping, water use reduction, and construction debris management. Mid-size commercial buildings don't need to meet LEED certification requirements but must

meet LEED standards for building commissioning, landscaping, water use, and construction debris management starting in 2009, and must meet enhanced commissioning standards and tighter water use requirements starting in 2010. Beginning in 2012, the buildings must also meet LEED standards for the use of on-site renewable energy or the purchase of renewable energy credits.

The toughest requirements apply to large commercial buildings. Starting in November, new permit applications for high-rise residential building must submit documentation to achieve LEED certification, and that requirement ratchets up to LEED Silver in 2009 and LEED Gold in 2012. There are also requirements to meet additional LEED standards, nearly equal to those for mid-size commercial buildings. Finally, for new large commercial interiors and major alterations to existing buildings, new permit applications must include documentation to achieve the same LEED rating requirements as for new large commercial buildings, and must also meet the LEED standards for materials that emit low levels of indoor pollutants. All new buildings must earn additional rating points if an older building was demolished to make room for it, and they must earn even higher points if the demolished building was historical. Building projects can also earn extra points by retaining historical features of the previous building.

Earning LEED credits within this framework is becoming cost neutral for most hotel developers, especially in the Napa Valley where the industry has caught up to speed. Since at least March 2008, green property builders have been giving them "real figures on what it costs to build a green property" after developer tax incentives.

## **Virginia**

Charlottesville, Virginia became one of the first small towns in the United States to enact green building legislation. This presents a significant shift in construction and architecture as LEED regulations have formerly been focused on commercial construction. If US homeowner interest grows in "green" residential construction, the companies involved in the production and manufacturing of LEED building materials will become likely candidates for tomorrow's round of private equity and IPO investing.

## **Washington**

In 2005, Washington State became the first state in the United States to enact green building legislation. According to the law, all major public agency facilities with a floor area exceeding 5,000 square feet (465 m<sup>2</sup>), including state funded school buildings, are required to meet or exceed LEED standards in construction or renovation. The projected benefits from this law are 20% annual savings in energy and water costs, 38% reduction in waste water production and 22% reduction in construction waste.