Green Buildings

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***Abstract*—**Humans are unique amongst all species with respect to control over their destinies. Humans, individually and in groups can anticipate and prepare for the future to a much greater degree than ecological systems. People use mental models of varying complexity and completeness to construct views of the future. People have developed elaborate ways of exchanging, influencing and updating these models. This creates complicated dynamics based upon access to information, ability to organize, and power. In contrast the organization of ecological systems is a product of the mutual reinforcement of many interacting structures and processes that have emerged over long periods of time. Similarly behaviour of plants and animals is the product of successful evolutionary experimentation that has occurred in the past. Consequently the arrangement and behaviour of natural systems are based upon what has happened in the past, rather than looking in anticipation towards the future. The difference between forward thinking human systems and backwards-looking natural systems is fundamental. It means that understanding the role of people in ecological systems requires not only understanding how people have acted in the past, but also how they think about the future.

The term green building refers to the quality and characteristics of the actual structure created using the principles and methodologies of sustainable construction. Green Buildings can be defined as "healthy facilities designed and built in a resource efficient manner, using ecologically based principles". Similarly, ecological design, ecologically sustainable design, and green design are terms that describe the application of sustainability principles to building design. Despite the prevalent use of these terms, truly sustainable green commercial buildings with renewable energy systems, closed materials loops, and full integration into the landscape are rare to non-existent. Most existing green buildings feature incremental improvement over, rather than radical departure from, traditional construction methods. Nonetheless, this process of trial and error, along with gradual incorporation of sustainability principles, continues to advance the industry's evolution towards the ultimate goal of achieving complete sustainability throughout all phases of the built environment's life cycle.

***Keywords*—**Green Buildings, Nature, Sustainability, Sustainable Construction.

I. Introduction

According to Sim Van Der Ryn and Stuart Cowan, the authors of Ecological Design, design in its simplest form can be defined as "…the intentional shaping of matter, energy and process to meet a perceived end or desire". In contrast to their definition of design, Van Der Ryn and Cowan define ecological design as that which transforms matter and energy using processes that are compatible and synergistic with nature and that are modelled on natural systems. The ecological problems we face today, such as climatic change and biodiversity loss, reflect a botch of design. The disconnection of human design from nature is precisely the problem that high-performance green building, through the application of ecological design seeks to address.

Contemporary ecological designers are engaged in a tussle with the archetypal approach which incorporates machine-oriented design in the form of buildings and infrastructure; and the industrial products encompassing buildings are still being shaped on concepts, design tactics, and processes that have their origins in the industrial renaissance. They attempt to shift to a form of thinking that would reconnect humans and nature. It can be documented as follows:

- Understanding ecology and its applicability to the built environment.
- Determining how to use nature as a prototypical and/or metaphor for design.
- Coping with an industrial production system that operates using conformist thinking.
- Retrogressing at least two centuries of design that used the machine as its prototype and metaphor.

The Federal Management Program (FEMP) recently published a list of the benefits that address a broad range of economic, environmental and social issues that a shift to sustainable design can provide.

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TABLE I

	Economic	Societal	Environmental
Siting	Reduced costs for site preparation, parking lots, roads	Improved aesthetics, more transportation options for employees	Land preservation, reduced resource use, protection of ecological resources, soil and water conservation, restoration of brownfields, reduced energy use, less air pollution
Water Efficiency	Lower first costs, reduced annual water and waste-water costs	Preservation of water resources for future generations and for agricultural and recreational uses; fewer waste water treatment plants	Lower potable water use and reduced discharge to water ways; less strain on aquatic ecosystems in water-short areas; preservation of water resources for wildlife and agriculture
Energy Efficiency	Lower first costs, lower fuel and electricity costs, reduced peak power demand, reduced demand for new energy infrastructure	Improved comfort conditions for occupants, fewer new power plants and transmission lines	Lower electricity and fossil fuel use, less air pollution and fewer carbon dioxide emissions, lower impacts from fossil fuel production and distribution
Materials and Resources	Decreased first costs for reused and recycled materials, lower waste disposal costs, reduced replacement costs for durable materials, reduced need for new landfills	Fewer landfills, greater markets for environmentally preferable products, decreased traffic due to use of local/regional materials	Reduced strain on landfills, reduced use of virgin resources, better managed forests, lower transportation energy and pollution, increase in recycling markets
Indoor Environment Quality	Higher productivity, lower incidence of absenteeism, reduced staff turnover, lower insurance costs, reduced litigation	Reduced adverse health impacts, improved occupant comfort and satisfaction, better individual productivity	Better indoor air quality, including reduced emissions of organic compounds, carbon dioxide, and carbon monoxide
Commissioning; Operations and Maintenance	Lower energy costs, reduced occupant/owner complaints, longer building and equipment lifetimes	Improved occupant productivity, satisfaction, health and safety	Lower energy consumption, reduced air pollution and other emissions

II. Site Selection

Land use and landscape design are closely coupled; they offer the greatest prospect for innovation in the application of the resources needed to create the build environment. Prudently designed and executed work by architects, landscape architects, civil engineers and construction mangers is required to produce a building that is highly assimilated with the local ecosystem; that carefully considers the site's geology, topography, solar insolation, hydrology and wind patterns; that minimizes impacts during construction and operation; and that employs landscaping as a dominant adjunct to its technical systems. The location of the facility on the site, the type and colour of peripheral finishes, and the materials used in parking and paving all effect the thermal load on the structure, and hence the design of the heating and cooling systems by the mechanical engineer. Curtailing the influence of light pollution requires the electrical engineer to cautiously design exterior lighting systems to eradicate unnecessary illumination of the building's surroundings. Providing access to mass transportation, encouraging bi-cycling and alternate-fuel vehicles ensures that the context of the building is not neglected. Collaboration among all these players makes high-performance green building as a distinctive delivery system and is vital to make optimal use of the site and landscape. There are many categories of fronts to land use that is aligned with the concept of green buildings. They are of pivotal importance because buildings use several categories of resources for their creation and operation: materials, energy, water and land. Land obviously is an essential and valuable resource and therefore its appropriate use is of prime consideration in the development of high-performance green building.

- Building on land that has been previously utilized instead of on land that is valuable from and ecological point of view
- Protecting and preserving wetlands and other features that are key elements of existing ecosystems
- Using native and adopted, drought tolerant plants, trees and turf for landscaping
- Developing brownfields, properties that are contaminated or perceived to be contaminated
- Developing grayfields, areas that were once building site in urban areas
- Reusing existing buildings instead of constructing new ones
- Protecting key natural elements and integrating them into the building project for both amenity and function
- Minimizing impacts of construction on the site by minimizing the building footprint and carefully planning construction operations
- Minimizing earth moving and compaction of soil during construction
- Fully using the sun, prevailing winds, and foliage on the site in the passive solar design scheme

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- Maintaining as much as possible the natural hydro period of the site
- Minimizing impervious areas on the site through appropriate location of the building, parking and other paving
- Using alternate stormwater management technologies such as pervious pavement, bioretention, rainwater gardens, and others, which assist on site or regional groundwater and aquifer recharge
- Minimizing heat island effects on the site by using light coloured paving and roofing, shading and green roofs
- Eliminating light pollution through careful design of exterior lighting systems
- Using natural wetlands to the maximum extent possible in the stormwater management scheme and minimizing the use of dry-type retention ponds
- Using alternate stormwater management technologies such as pervious concrete and asphalt for paved surfaces

These cover a wide range of possibilities and their general purpose is to integrate nature and buildings, reuse sites that have already been impacted by human activities, and minimize disturbances caused by the building project

III. Planning

Creating a low energy profile is a major challenge for designers of high-performance buildings. The environmental impact of extracting and consuming non-renewable energy resources such as fossil fuels and nuclear energy are profound. Pronounced land impacts from coal and uranium mining, acid rain, nitrous oxides, particulates, radiation and ash disposal problems, and long term storage of nuclear waste are just some of the consequences of energy consumption by the built environment. For the built environment, truly dramatic reductions in energy consumption, accompanied by tremendous progress in passive design, will be needed to meet a potentially costly-energy future.

A green building would ideally use very little energy and renewable energy would be the source of most of the energy needed to heat, cool, and ventilate it. Today's green buildings include a wide range of innovations that are starting to change the energy profile of typical buildings. The strategies used to heat, cool, ventilate and light green high performance buildings allow a significant downsizing of the mechanical plant and a parallel reduction in the overall capital costs of the building. This is clearly the ideal outcome, wherein both capital and operating costs of the building are lower than those of a comparable base-case building. The basic steps in designing an energy efficient building are as follows:

- Use building simulation tools to assist designers in minimizing energy consumption.
- Optimize passive solar design of the building.
- Maximize the thermal performance of the building envelope.
- Minimize internal building loads.
- Design an efficient HVAC system that minimizes energy use.
- Incorporate renewable energy use to the maximum extent possible.
- Harvest waste energy through combined heat and power (CHP) systems, cogeneration, ventilation/exhaust air energy recovery, and other means.
- Incorporate innovative emerging strategies where appropriate – for example, ground coupling and radiant cooling.

IV. Design Strategy

Passive design must be the catalysis for any high-performance green building due to the complexity of energy system design. Passive design is the design of the building's heating, cooling, lighting, and ventilation systems, relying on sunlight, wind, vegetation, and other naturally occurring resources on the construction site. The use of natural energy sources like the sun and the wind are critical before opting for any external measures to reduce energy consumption. Before the incorporation of any active or powered systems, it will predict the energy character of a building. A building that has been well designed in a passive sense could be disconnected from its active energy sources and still be judiciously functional due to daylighting, adequate passive heating and cooling, and ventilation being provided by the passive design features. A successful passive design scheme creates a truly climate-responsive, energy-conserving building offering a wide range of remunerations.

Passive design has two major aspects: (1) the use of the building's location and site to reduce the building's energy profile and (2) the design of the building itself – its orientation, aspect ratio, massing, fenestration, ventilation paths, and other measures. It is multifaceted, as it depends on many factors, including latitude, altitude, solar insulation, heating and cooling degree days, humidity patterns, annual wind strength and direction, the presence of trees and vegetation, and the presence of other structures. An augmented passive design can greatly moderate the energy outlays of heating, cooling, ventilation and lighting. Some of the dynamics that should be included in the development of a passive design strategy are:

- *Local Climate:* Sun angles and solar insulation, wind velocity and direction, air temperature and humidity throughout the year
- *Site Conditions:* Terrain, vegetation, soil conditions, water table, microclimate, relationship of other buildings
- *Building Aspect Ratio:* Ratio of the building's length to its width
- *Building Orientation:* Long axis oriented east-west, room layout, glazing
- *Building massing:* Energy storage potential of materials, fenestration, colour
- *Building use:* Occupancy schedule and use profile
- *Daylighting strategy:* Fenestration, daylighting devices

- *Building envelope:* Geometry, insulation, fenestration, doors, air leakage, ventilation, shading, thermal mass, colour
- *Internal loads:* lighting, equipment appliances, people
- *Ventilation strategy:* Cross-ventilation potential, paths for routine ventilation, chimney effect potential

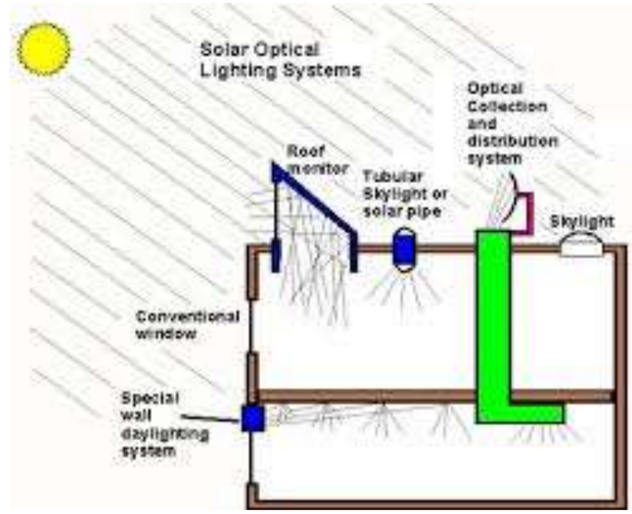
The optimum building orientation, the location and varieties of windows, the usage of daylighting, and numerous other decisions must be based on a careful inspection of the condition found in each milieu.

A. Daylighting

When man moved indoors, for two or more centuries since the industrial revolution daylight had been too valuable an asset to waste. Architects responded by a whole topology of window and rooflight designs, readily accepting the need for shallow plans, light wells and courtyards. This constraint was also reinforced by the same need for shallow plan to achieve good natural ventilation. Although artificial lighting was necessary, daylight was the preferred option during the sun-lit hours. Over a period of time artificial lighting made great strides and improvements both technically and economically whereby it became feasible to provide the entre working light artificially. These contradictory influences meant that daylighting over a period of time was virtually lost. The conflicting issues of daylighting versus cooling the building have played a detrimental role in the trade-offs during developing an effective daylighting strategy.

The effective use of louvers, low-emissivity glasses, and slanted ceilings will help in creating a stimulating environment which increases productivity, allowing the building occupants to comfortably “experience a day in nature”. Daylighting could be coupled with an effective lighting system could tremendously reduce the expenditure incurred.

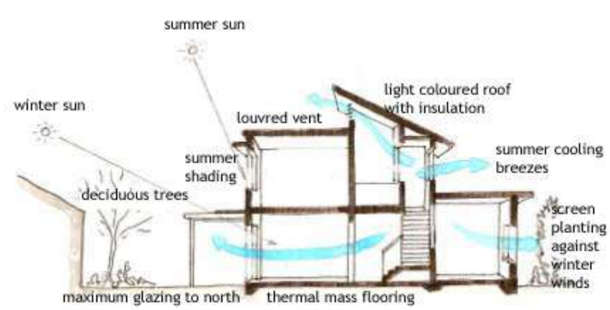
For total energy conservation and comfort, solar detectors can be used to track the sun’s angle and intensity along with other sensors to provide a fully automated solution. Constant lighting control can be used to dim perimeter light fittings within an office area linked to an external solar monitoring control. The external weather station can monitor the suns angle, position and intensity around the building. This data can then be used to motor the blinds to the correct position to reduce glare and solar internal heat gain.



Lighting is an insatiable consumer of electrical energy; thus the inevitable target of any design should be increase the dependence on natural daylighting and minimizing the use of artificial lighting. This can only be achieved by an integrated solution where optimal and effective lighting methodologies are adopted. Some methods that have repeatedly proven effective are the adoption of upcoming technologies such as the use of fluorescent lighting, Light Emitting Diode (LED) lights, Fiber optic lighting, etc… Fiber optic lighting is exceptionally capable in the fact that it can deliver daylights even in those areas where luminosity is minimal due to the conspicuous absence of a window, panel or roof slit. Research has shown that an integrated lighting system has the capability to reduce the consumptive capacity by over 50 percent.

B. Passive Ventilation

Passive or natural ventilation is gaining prominence of late to mechanical ventilation or full-air conditioning. Wind generates pressure differences across the constructed environment through openings in the building envelope. Furthermore the temperature differences between the interior and the exterior of the building causes a vertical pressure gradient which causes air to flow vertically – if the wind inside is warmer than that of the outside. This is known as the buoyance flow or the stack effect. These two are present simultaneously and are also highly variable which creates a hindrance in the effective natural ventilation. Ventilation can also be achieved through the use of ducts and chimneys.



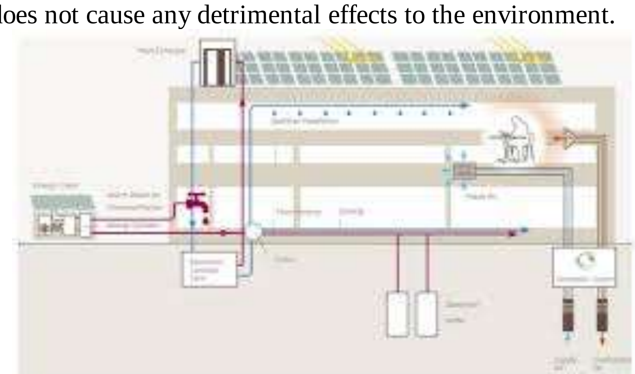
Natural and mechanical ventilation need not be mutually exclusive. Certain spaces in a building would obviously necessitate the use of mechanical ventilation, if they are internal or have high ventilation demands such as toilets and kitchens.

Natural ventilations can achieve high levels of comfort but cannot provide consistent and uniform conditions as mechanical systems. Other factors which have to be considered include outdoor conditions, as in the case of a noisy or polluted environment.

V. Renewable Energy Systems

Renewable energy systems have to be integrally incorporated with the conventional energy sources. The cost of electricity is increasing at a rapid pace. Very soon humanity will reach a stage where the energy required to procure fossil fuels will be higher than that the energy value of the fuel itself. With such a scenario looming ahead, renewable energy sources and systems provide the necessary solution. They can basically be classified into three different segments namely solar energy, wind energy and biomass.

Photovoltaic cells are expedients that convert sunlight into electrical energy. They come with a plethora of benefits attached. They have no moving parts and hence have a large life-span. The energy generated can be directly used and if in excess can be sent to the grid. They can also be fabricated into different forms and can be used or integrated into the various parts of the building to maximize the coverage area. They can also be automated with solar reflectors and sensors to optimize their performance using optimal angle technology. They are also pollution free and cause no carbon footprint during their lifespan. They are also highly flexible infrastructure and can be added, removed or reused in other applications. At the end of their lifespan their disposal also does not cause any detrimental effects to the environment.



Small wind turbines may be attached to the roof to generate enough power to light a small building provided that there is enough wind velocity and that the load requirement of the building is not high.

Biomass refers to any plant derived organic matter available on a renewable basis, including dedicated energy crops and trees, agricultural food and feed crops, agricultural crops and residues, aquatic plants, animal wastes, municipal wastes and other waste materials.

Depending on the building, bio-wastes will vary. Anaerobic decomposition produces biogas and yields good manure which is rich in nitrogen, free from pollution and pathogens, and reduces the chances of communicable diseases. Due to social resistance it cannot be utilized as a fuel for cooking. For a residential building, the sewage can be collected and composted in electric composters of varying capacities, and the manure obtained can be either used as fertilizer in the flora in and around the building perimeter or it can also be sold to obtain economic benefits.

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