Zero-Energy and Carbon-Neutral Construction: Where and How to Start Integrating the Concepts into Construction Education?

Erdogan Sener, IUPU-Indianapolis

Abstract

Buildings in developed countries account for 40% of the total energy consumption today and in parallel account for 40% of global greenhouse gas emissions even though buildings themselves do not emit carbon dioxide directly.

Despite the fact that green, carbon-neutral, and zero-energy issues have been heavily design focused so far it is inevitable that construction engineering professionals will also play a major part in these undertakings in due time. Hence the need to include and integrate these core concepts into construction engineering and management education and related curricula. This will ensure that these fundamentals are conveyed to the future generation of professionals who will surely play a major role in the implementation of the core concepts.

This paper focuses on starting, however slowly, with the coverage of the core issues behind zero-energy, carbon neutral and sustainable design/construction. Work is being undertaken by U.S. Green Building Council (USGBC) and others to rate new buildings and renovations have been used as a basis for conveying of the fundamental concepts. Typical technologies and methodologies that have been implemented so far towards this end are touched upon. Examples of how the fundamental concepts have been integrated into typical courses are covered.

Key Words

Educating for Sustainable Energy

Zero-Energy and Carbon-Neutral Construction: Where and How to Start Integrating the Concepts into Construction Education?

Erdogan M. Sener[1]
Indiana University–Purdue University Indianapolis (IUPUI)

Introduction

Buildings in developed countries account for 40% of the total energy consumption today and in parallel account for 40% of global greenhouse gas emissions even though buildings themselves do not emit carbon dioxide directly. According to research conducted by the United States Green Building Council (USGBC), the United States' buildings account for [1]:

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

Buildings that use no energy from external sources such as a power grid and produce their own energy for self sufficiency are called zero-energy (ZE) buildings. These would also be carbon-neutral (CN) buildings but there could be other ways of achieving carbon neutrality based on carbon trading etc. Even though energy saving features of buildings remain as significant issues as ever in building design and construction in general, the bar has been raised further to make buildings zero-energy and/or carbon-neutral. This development is very similar to the efforts in the auto industry and other manufacturing industries to minimize environmental impacts in their operations and of their resultant products, whether by mandates or otherwise. The construction industry has, for some time, started doing the same by trying to reduce carbon emissions and energy consumption related to production of construction materials, their transportation, and from operation of buildings themselves, without having to conform to some mandates that may eventually come.

The ultimate purpose is to produce construction materials with minimal energy and resultant carbon emissions; materials that can be used, recycled, and later re-used, as well as, design and construct buildings that are self-sufficient in energy use and have carbon neutral emissions. The aim is to have significant energy savings by year 2010 for all buildings and all new buildings to be carbon-neutral by 2030.

Realizing that this is a highly design related issue, AIA (American Institute of Architects) and the U.S. Conference of Mayors, involving more than 400 mayors in the U.S., have started promoting sustainable building designs through appropriate design approaches. The assessment checklists and systems developed nationally and internationally by LEED (Leadership in Energy and Environmental Design), NAHB (National Association of Home Builders), GBI (Green Building Initiative), North American Coalition for Green Buildings, BREEAM (Building research Establishment Environmental Assessment Method), and CASBEE (Comprehensive Assessment System for Building Environmental Efficiency) rate buildings in terms of their incorporation of energy efficiency and sustainability in building design and have provided the necessary momentum towards the above stated goals.

Zero-Energy and Carbon-Neutral Construction – Green Design and Construction

Green Design and Green Construction as the umbrella for zero-energy and carbon-neutral construction refers to design and construction practices that take into consideration a number of environmental issues and the associated technologies [8,9,10,11,12,13,14,16] . Examples include use of renewable or recycled resources and materials, utilization of non-toxic building materials, conservation of energy, efficient use of utilities (e.g., water and power), use of natural lighting, improving indoor air-quality, building reuse, sorting of materials waste, better placement of facilities on site, and preservation of natural vegetation.

Despite the fact that the buildings in the U.S. consume one-third of the total energy, two-thirds of total electricity, one-eighth of all water used, currently, only about 3 % of the new construction in the USA has some green features. However, the increasing interest in green facilities has given momentum to adopting the guiding principles for green solutions and alternatives that have fewer adverse environmental consequences, enhance the aesthetics, and are economically feasible. As described by the United States Green Building Council, USGBC [1] , Green design not only makes a positive impact on public health and the environment, it also reduces operating costs, enhances building and organizational marketability, potentially increases occupant productivity, transforms land to provide valuable ecological resources and helps create a sustainable community [23] .

At the present time, there are two principal organizations that provide measures of assessment of green design and construction in the U.S. These organizations are:

- The US Green Building Council (USGBC) - is probably the most established organization that is focused on green design and construction. It has developed an assessment system known as Leadership in Energy and Environmental Design (LEED). This assessment system is tailored to a number of specialties: LEED-NC addresses New Commercial Construction and major renovation projects, LEED-EB addresses Existing Building operations, LEED-CI addresses Commercial Interiors projects, LEED-CS addresses Core and Shell projects, LEED-H addresses Homes, and LEED-ND addresses Neighborhood Development [1] .

- The National Association of Home Builders (NAHB) – is an organization that dedicates significant efforts to green home construction. It also has developed a system known as Green Home Building Guidelines to assess the level of conformance to the green construction principles in residential construction [5] .

Despite being the oldest and being seen as the de facto industry standard at the moment, the LEED assessment system has come under some criticism. USGBC has taken note and is trying to address the issues. Nevertheless, other organizations have emerged with their own systems to cover the LEED shortcomings, to cover the kinds of construction LEED did not cover at the beginning, or to oppose the ways LEED is implemented. Examples of such organizations include:

- The Green Building Initiative (GBI) [17] -The Green Building Initiative (GBI) has also been created to promote green building practices. GBI was introduced to the U.S market as an alternative to the U.S. Green Building Council (USGBC) operations. It promotes the use of the National Association of Homebuilders' (NAHB) Model Green Home Building Guidelines. GBI is the first green building organization to become accredited by ANSI (American National Standards Institute). It has also focused on the non-residential building market through "Green Globes" [18] , an associated assessment tool of Canadian origin which has licensed its assessment system for use in the U.S.A.

- North American Coalition on Green Building [6] - The North American Coalition on Green Building, on the other hand, is a coalition of 30 or so trade associations (most of them wood and plastics associations in the United States and Canada) formed in response to the USGBC's policy of excluding trade groups from membership in their organization. The Coalition has been developed to monitor the USGBC activities and oppose adoption of LEED as a mandatory requirement at the state and local levels. It is thus an interest group trying to protect the interests of its members in green building activities.
- There are other industry groups, such as the Wood Promotion Network, which have been created due to objections to a number of provisions in the American Coalition on Green Building

The U.S. is benefiting from the undertakings in the green design and construction arena and will benefit more from this healthy competition between assessment methodologies. It is inevitable that in time all such entities will move closer to mutually acceptable, rational, and practical means of defining green design and construction and its assessment. A culture sensitive to environmentally conscious design and construction is evolving to the benefit of mankind everywhere. In parallel with these developments, it is imperative that green design and construction fundamentals be introduced in the construction curricula of construction education programs so that the future generation which will carry the baton for further acceptance and implementation of these methods and technologies begin to understand the basic principles.

Issue and Assessment Criteria Employed in Green Design and Construction

No matter which one of the above entities are involved in the assessment of green design and construction, the assessment criteria has evolved into something more or less common for all in terms of main focus in the different assessment methodologies. The following are derived specifically from the USGBC based LEED criteria [1] to illustrate the main issues considered and addressed, however, others emphasize essentially the same:

- Site selection and sustainability issues related to project sites in terms of prevention of pollution, ensuring development density and community connectivity; providing opportunities for implementing of alternative means of transportation; site modifications with emphasis on restoring and protecting the environment and maximizing open space; proper storm-water drainage design both in terms of quality and quantity of storm-water; minimization of heat island effect on roofs and other surfaces; and reduction of light pollution.
- Reduction of use of water both for landscaping and potable water uses and enhancing the efficiency of such use.
- Optimizing energy use and enhancing the efficiency of energy use through focusing on energy performance; refrigerant management; using on-site renewable or green energy; and modeling of expected energy use for measurement, optimization, and verification of expected outcomes.
- Materials and resources use with emphasis on re-using of existing building components and materials; increasing use of recycled materials or materials that can be recycled; using of regional materials; and using quickly renewable materials.
- Quality of the indoor environment in terms of IAQ(indoor air quality); smoke control; use of low emitting materials and increased ventilation; using daylight; controlling thermal and lighting comfort, chemicals, and pollutants through appropriate mechanical, electrical, and computer systems.

- Ensuring innovation in design that adheres to the underlying principles listed above and use of a professional(s) to supervise the related processes to make this happen.

For each of the entities involved in green design and construction, associated with each of the assessment criteria group given above, there are sub-items that detail the technologies that can be employed. Some of these are required or prerequisite for getting credit for fulfillment of the other sub-criteria in each group.

Green Technologies Employed in Green Design and Construction

Typical technologies and strategies employed for achieving green construction, like the assessment criteria, have merged quite a bit towards a common set [1,5,8,9,10] . Some of these are briefly summarized below together with the assessment criteria under which they find application. Even though USGBC-based LEED technologies are listed below for the most part, they are typical of almost all the assessment technologies employed in practice nowadays. They have been simplified by the author to make them more generic for use in diverse situations. Lately there has been some criticism of the LEED weight points attributed to each criteria. Still, these have been listed below, in parenthesis, to reflect the importance originally foreseen for each specific area even though this paper is about the fundamental concepts rather than detailed application. The issue is that some of the LEED points/weights are perceived as not being appropriate in terms of the work they require in the assessment process and their contribution of the fulfillment of the main objective of achieving green buildings and environments. It must be kept in mind that that the discussion below is for the NC (New Construction) area of LEED [1]. It is also to be noted that these prescribed technologies are for the U.S.

1. Sustainable Sites (14)

- Criteria: Prevention of construction activity pollution through controlling soil erosion, waterway sedimentation and airborne dust generation. *Technologies:* Use an erosion and sedimentation control plan during the design phase. Employ temporary and permanent seeding, mulching, earth dikes, silt fencing, sediment traps and sediment basins.

- Criteria: Avoiding of development of inappropriate sites in site selection and reduction of the environmental impact from the location of a building on a site. *Technologies:* Giving preference to sites that do not include sensitive site elements and restricting land types in site selection. Designing buildings with the minimal footprint to minimize site disruption of environmentally sensitive areas.

- Criteria: Ensuring proper development density and community connectivity through channeling development to urban areas with existing infrastructure, protecting greenfields (i.e. undeveloped land) and preserving habitat and natural resources. *Technologies*: Giving preference to urban sites with pedestrian access to a variety of services in site selection.

- Criteria: Brownfield (i.e. land previously used for industrial purposes, or certain commercial uses and may have real or perceived environmental contamination) redevelopment through rehabilitating damaged sites where development is complicated by environmental contamination and reducing pressure on undeveloped land. *Technologies:* giving preference to brownfield sites, identifying tax incentives and property cost savings for such sites, coordinating site development plans with remediation activity.

- Criteria: Promoting of alternative transportation opportunities through provision of public transportation access, bicycle storage and changing rooms; encouraging use of low emitting and fuel efficient vehicles; and provision of appropriate parking space to promote the above so that pollution and land development impacts from motor vehicle use are reduced. *Technologies:* Performing a transportation study to identify transportation needs, locating buildings near mass transit, designing buildings with transportation amenities such as bicycle racks and showering and changing facilities. Providing transportation amenities such as alternative fuel refueling stations and considering sharing the costs and benefits of refueling stations with neighbors. Minimizing parking lot/garage size and sharing parking facilities with adjacent buildings. Considering alternatives that will limit the use of single occupancy vehicles.

- Criteria: Protecting or restoring habitat and maximizing open space in site selection in order to conserve existing natural areas and restore damaged areas to provide habitat. Promote green areas through provision of a high ratio of open land area to construction area. *Technologies:* On greenfield sites, perform a site survey to identify site elements and adopt a master plan for development of the project site. Carefully site the building to minimize disruption to existing ecosystems and design the building to minimize its footprint. Strategies include stacking building construction, tuck-under parking (where some or all of the ground floor area is used for parking instead of living space) and sharing facilities with neighbors. Establish clearly marked construction boundaries to minimize disturbance of the existing site and restore previously degraded areas to their natural state. For previously developed sites, utilize local and regional agencies, consultants, educational facilities, and societies as resources for the selection of appropriate plant materials that require minimal or no irrigation following establishment, do not require active maintenance such as mowing or chemical inputs, and promote habitat value and biodiversity.

- Criteria: Appropriate design of stormwater drainage to control quantity and quality of flow in order to limit disruption of natural water hydrology by reducing impervious cover, increasing on-site infiltration, reducing or eliminating pollution from stormwater runoff, and eliminating contaminants by managing storm-water runoff. *Technologies:* Designing the project site to maintain natural stormwater flows by promoting infiltration. Specify vegetated green roofs [16, 20, 22], pervious paving, and other measures to minimize impervious surfaces. Reuse stormwater for non-potable uses such as landscape irrigation, toilet and urinal flushing and custodial uses. Use alternative surfaces (e.g., vegetated roofs, pervious pavement or grid pavers) and nonstructural techniques (e.g., rain gardens, vegetated swales, disconnection of imperviousness, rainwater recycling) to reduce imperviousness and promote infiltration. Use sustainable design strategies to design integrated natural and mechanical treatment systems such as constructed wetlands, vegetated filters, and open channels to treat stormwater runoff.

- Criteria: Minimizing heat island effect (thermal gradient differences between developed and undeveloped areas) on roof and non-roof surfaces to minimize impact on microclimate and human and wildlife habitat [19,21]. *Technologies:* Shade constructed surfaces on the site with landscape features and utilize high-reflectance materials for all non-plant elements of landscaping. Consider replacing constructed surfaces (i.e. roof, roads, sidewalks, etc.) with vegetated surfaces such as vegetated roofs [16, 20, 22, 24, 25] and open grid paving or specify high-albedo materials to reduce the heat.

- Criteria: Light pollution reduction through minimizing light trespass from the building and site, reducing sky-glow to increase night sky access, improving nighttime visibility through glare reduction, and reducing development impact on nocturnal environments. *Technologies:* Adopt site lighting criteria to maintain safe light levels while avoiding off-site lighting and night sky pollution. Minimize site lighting where possible and model the site lighting using a computer model. Technologies to reduce light pollution include full cutoff luminaries, low-reflectance surfaces and low-angle spotlights.

2. Water Efficiency (5)

- Criteria: Ensuring water use efficiency through limiting or eliminating the use of potable water, or other natural water resources for landscape irrigation. *Technologies:* Perform a soil/climate analysis to determine appropriate plant material and landscape types and design the landscape with appropriate plants to reduce or eliminate irrigation requirements. Where irrigation is required, use high-efficiency equipment and/or climate-based controllers. Consider using stormwater, greywater, and/or condensate water for irrigation.

- Criteria: Employing innovative wastewater technologies to reduce generation of wastewater and potable water demand, reduction of water use to reduce the burden on municipal water supply and wastewater systems, and increasing the local aquifer recharge. *Technologies:* Specifying high-efficiency fixtures and dry fixtures such as composting toilet systems, non-water using urinals, and occupant sensors. Consider reusing stormwater or greywater for sewage conveyance or on-site wastewater treatment systems (mechanical and/or natural) and for non-potable applications such as toilet and urinal flushing and custodial uses. Consider other options for on-site wastewater treatment including packaged biological nutrient removal systems, constructed wetlands, and high-efficiency filtration systems.

3. Energy & Atmosphere (17)

- Criteria: Fundamental and enhanced commissioning of the building energy systems to verify that these are installed and calibrated to perform according to the owner's project requirements, basis of design, and construction documents. *Technologies:* Considerations to include water-using systems, building envelope systems, and other systems in the scope of the commissioning plan as appropriate. The building envelope is an important component of a facility which impacts energy consumption, occupant comfort and indoor air quality. Consider building envelope modeling for significant financial savings and reduced risk of poor indoor air quality.

- Criteria: Establishing and ensuring the minimum level of energy efficiency for the proposed building and systems. *Technologies:* Designing the building envelope, HVAC, lighting, and other systems to maximize energy performance. Using relevant heating, refrigeration, and air-conditioning manuals or computer simulation modeling to ensure fulfillment of this prerequisite. If a local energy or similar code has demonstrated quantitative and textual equivalence follow the standards prescribed by this commercial energy code as a minimum.

- Criteria: Fundamental or more enhanced Refrigerant Management to reduce ozone depletion and support compliance with the protocols for minimizing direct contributions to global warming. *Technologies:* Promote use of non- CFC refrigerant equipment. If possible design and operate the facility without mechanical cooling and refrigeration. Use HVAC and refrigeration systems that minimize direct impact on ozone depletion and global warming. Select HVAC&R equipment with reduced refrigerant charge and increased equipment life. Maintain equipment to prevent leakage of refrigerant to the atmosphere. Utilize fire suppression systems that do not contain HCFCs or Halons.

- Criteria: Optimizing energy performance for achieving increasing levels of energy performance to reduce environmental and economic impacts associated with excessive energy use. *Technologies:* Design the building envelope and systems to maximize energy performance. Use a computer simulation model to assess the energy performance and identify the most cost-effective energy efficiency measures. Quantify energy performance as compared to a baseline building. If a local energy or similar code has demonstrated quantitative and textual equivalence following, at a minimum, observe the standards prescribed by this commercial energy code.

- Criteria; Encourage and recognize increasing levels of on-site renewable energy self-supply in order to reduce environmental and economic impacts associated with fossil fuel energy use. *Technologies:* Assess the project for non-polluting and renewable energy potential including solar, wind, geothermal, low-impact hydro, biomass and bio-gas strategies. When applying these strategies, take advantage of net metering with the local utility.

- Criteria: Provide for the ongoing accountability of building energy consumption over time. *Technologies:* Develop plans to evaluate building and/or energy system performance on an ongoing basis. Characterize the building and/or energy systems through energy simulation or engineering analysis. Install equipment to measure energy use. Track performance by comparing predicted performance to actual performance. Evaluate energy efficiency by comparing actual performance to baseline performance.

- Criteria: Encourage the use of green power through development and use of grid-source and renewable energy technologies on a net zero pollution basis. *Technologies:* Determine the energy needs of the building and investigate opportunities to engage in a green power contract. Green power is derived from solar, wind, geothermal, biomass or low-impact hydro sources or other sources of green power may be available. Renewable energy certificates (RECs), tradable renewable certificates (TRCs), green tags and other forms of green power that comply with Green-e’s technical requirements can be used. See www.green-e.org for details.

4. Materials & Resources (13)

- Criteria: Facilitate the reduction of waste generated by building occupants that is hauled to and disposed of in landfills through storage and collection of recyclables. *Technologies:* Coordinate the size and functionality of the recycling areas with the anticipated collection services for glass, plastic, office paper, newspaper, cardboard and organic wastes to maximize the effectiveness of such areas. Consider employing cardboard balers, aluminum can crushers, recycling chutes and collection bins at individual workstations to further enhance the recycling program.

- Criteria: Building Reuse through maintaining and reuse of existing walls, floors and roof or of interior non-structural elements to extend the life cycle of existing building stock, conserve resources, retain cultural resources, reduce waste and reduce environmental impacts of new buildings as they relate to materials manufacturing and transport. *Technologies:* Reuse of existing, previously occupied buildings, including structure, envelope and elements. Removing elements that pose contamination risk to building occupants and upgrade components that would improve energy and water efficiency such as windows, mechanical systems and plumbing fixtures.

- Criteria: Construction waste management through diversion of construction, demolition and land-clearing debris from disposal in landfills and incinerators, redirecting recyclable recovered resources back to the manufacturing process, and redirecting reusable materials to appropriate sites. *Technologies:* Establishing methodologies for diversion of waste from disposal in landfills and incinerators and adopting a construction waste management plan to achieve these goals. Consider recycling cardboard, metal, brick, acoustical tile, concrete, plastic, clean wood, glass, gypsum wallboard, carpet and insulation. Designating a specific area(s) on the construction site for segregated or commingled collection of recyclable materials, and tracking recycling efforts throughout the construction process. Identifying construction haulers and recyclers to handle the designated materials.

- Criteria: Reusing building materials and products in order to reduce demand for virgin materials and to reduce waste, thereby reducing impacts associated with the extraction and processing of virgin resources. *Technologies:* Identify opportunities to incorporate salvaged materials into building design and research potential material suppliers. Consider salvaged materials such as beams and posts, flooring, paneling, doors and frames, cabinetry and furniture, brick and decorative items.

- Criteria: Increase demand for building products that incorporate recycled content materials and/or use materials that are recyclable, thereby reducing impacts resulting from extraction and processing of virgin materials.
  Technologies: Establish a project goal for recycled content materials and identify material suppliers that can achieve this goal. During construction, ensure that the specified recycled content materials are installed. Consider a range of environmental, economic and performance attributes when selecting products and materials.

- Criteria: Use and increase demand for building materials and products that are extracted, processed, and manufactured within the region, thereby supporting the use of local resources and reducing the environmental impacts resulting from transportation. *Technologies:* Establish a project goal for locally sourced materials, and identify materials and material suppliers that can achieve this goal. During construction, ensure that the specified local materials are installed and quantify the total percentage of local materials installed. Consider a range of environmental, economic and performance attributes when selecting products and materials.

- Criteria: Reduce the use and depletion of finite raw materials and long-cycle renewable materials by replacing them with rapidly renewable materials. *Technologies:* Establish a project goal for rapidly renewable materials and identify products and suppliers that can support achievement of this goal. Consider materials such as bamboo, wool, cotton insulation, agrifiber, linoleum, wheatboard, strawboard, cork, and wood certifiably obtained from rapidly growing renewable forests. During construction, ensure that the specified renewable materials are installed.

5. Indoor Environmental Quality (15)

- Criteria: Establish minimum indoor air quality (IAQ) performance to enhance indoor air quality in buildings, thus contributing to the comfort and well-being of the occupants. *Technologies:* Design ventilation systems to meet or exceed the minimum outdoor air ventilation rates as described by governing HVAC standards. Balance the impacts of ventilation rates on energy use and indoor air quality to optimize for energy efficiency and occupant health.

- Criteria: Minimize exposure of building occupants, indoor surfaces, and ventilation air distribution systems to Environmental Tobacco Smoke (ETS). *Technologies:* Prohibit smoking in buildings or effectively control the ventilation air in smoking rooms. For residential construction, prohibit smoking in common areas, design building envelope and systems to minimize ETS transfer among dwelling units.

- Criteria: Provide capacity for ventilation system for outdoor air delivery monitoring to help sustain occupant comfort and wellbeing. *Technologies :* Install carbon dioxide and airflow measurement equipment and feed the information to the HVAC system and/or Building Automation System (BAS) to trigger corrective action, if applicable. If such automatic controls are not feasible with the building systems, use the measurement equipment to trigger alarms that inform building operators or occupants of a possible deficiency in outdoor air delivery.

- Criteria: Provide additional outdoor air ventilation to improve indoor air quality for improved occupant comfort, well-being and productivity. *Technologies:* For mechanically ventilated spaces, use heat recovery, where appropriate, to minimize the additional energy consumption associated with higher ventilation rates. For naturally ventilated spaces follow the established best practices. Use software to analytically predict room-by-room airflows.

- Criteria: Construction of an IAQ Management Plan to be used during construction and before occupancy to reduce indoor air quality problems resulting from the construction/renovation process in order to help sustain the comfort and well-being of construction workers and building occupants. *Technologies:* Adopt an IAQ management plan to protect the HVAC system during construction, control pollutant sources and interrupt contamination pathways. Sequence the installation of materials to avoid contamination of absorptive materials such as insulation, carpeting, ceiling tile and gypsum wallboard. If possible, avoid using permanently installed air handlers for temporary heating/cooling during construction. Prior to occupancy, perform a building flush-out or test the air contaminant levels in the building. Determine appropriate specifications and schedules for filtration media.

- Criteria: Choose low-emitting adhesives, sealants, paints, coatings, carpet systems, composite wood and agrifiber products to reduce the quantity of indoor air contaminants that are odorous, irritating and/or harmful to the comfort and well-being of installers and occupants. *Technologies:* Specify low-VOC materials in construction documents. Ensure that VOC limits are clearly stated in relevant sections of the specifications. Common products to evaluate include: general construction adhesives, flooring adhesives, fire-stopping sealants, caulking, duct sealants, plumbing adhesives, and cove base adhesives. Track the VOC content of all interior paints and coatings during construction. Clearly specify requirements for product testing and/or certification in the construction documents. Select certified products for which testing has been done by qualified independent laboratories in accordance with the appropriate green requirements. Specify wood and agrifiber products that contain no added urea-formaldehyde resins. Specify laminating adhesives for field and shop applied assemblies that contain no added ureaformaldehyde resins.

- Criteria: Minimizing exposure of building occupants to potentially hazardous particulates and chemical pollutants through indoor chemical and pollutant source control. *Technologies:* Designing facility cleaning and maintenance areas with isolated exhaust systems for contaminants. Maintaining physical isolation from the rest of the regularly occupied areas of the building. Installing permanent entryway systems such as grills or grates to prevent entry of occupant-borne contaminants. Installing high-level filtration systems in air handling units processing both return air and outside supply air

- Criteria: Designing for and providing a high level of lighting system and thermal comfort control by individual occupants or by specific groups in multi-occupant spaces (i.e. classrooms or conference areas) to promote the productivity, comfort and well-being through systems that control lighting and thermal comfort. Providing for the assessment of building thermal comfort over time. *Technologies:* Design the building with occupant controls for lighting. Strategies to consider include lighting controls and task lighting. Integrate lighting systems controllability into the overall lighting design, providing ambient and task lighting while managing the overall energy use of the building. Install comfort controls to allow adjustments to suit individual needs or those of groups. Use governing HVAC standards that identify the factors of thermal comfort. Control systems may involve operable windows, hybrid systems integrating operable windows and mechanical systems, or mechanical systems alone. Individual adjustments may involve individual thermostat controls, local diffusers at floor, desk or overhead levels, or control of individual radiant panels, or other means integrated into the overall building, thermal comfort systems, and energy systems design. In addition, designers should evaluate the closely tied interactions between thermal comfort and acceptable indoor air quality, whether through natural or mechanical ventilation. Design building envelope and systems to ensure comfort criteria. Evaluate air temperature, radiant temperature, air speed, and relative humidity in an integrated fashion and coordinate these criteria.

- Criteria: Promotion of daylight and views for the building occupants through a connection between indoor and outdoor spaces by means of introduction of daylight and views into occupied areas. *Technologies:*

Design the building to maximize interior daylighting. Considerations should include building orientation, shallow floor plates, increased building perimeter, exterior and interior permanent shading devices, high performance glazing and automatic photocell-based controls. Predict daylight factors via manual calculations or model daylighting strategies with a physical or computer model to assess footcandle levels and daylight factors achieved. Design the space to maximize daylighting and view opportunities. Strategies to consider include lower partition heights, interior shading devices, interior glazing, and automatic photocell-based controls.

Criticisms associated with green design and construction systems' assessment methodologies

Despite being the oldest and being seen as the de facto industry standard at the moment, the LEED assessment system has come under a lot of criticism [2,3,4,7,15]. Some of these are summarized below.

- The assessment system is costly, construction owners are opting for forgoing certification in favor of eco-friendly features.
- Complex in implementation.
- Too heavy in bureaucratic requirements in terms of documentation requirements, review process, and commissioning.
- Disconnect or discrepancy between the points allocated to each of the criteria and the actual environmental benefits realized from implementation of these.
- About 300 buildings have been certified, more than 2,000 have been registered waiting for implementation of the process, quite a backlog and a three year lag in certification.
- Takes too long, many months in most cases.
- Points needed for certification may be accumulated without going much beyond the local building codes and governing HVAC standards.
- As is, it does not guarantee energy efficiency since adequate number of points for certification may be accumulated without energy saving related features, mandatory points for ensuring energy efficiency may be needed.
- Does not adequately stress the siting/location of a building which has an impact on energy use, traffic, and pollution.
- Burdensome and arbitrary, lacks scientific rigor and full of undue regulation.
- There are cheaper alternatives in terms of assessment methods and processes.
- There is no system for tracking building performance after completion.
- Some green projects have required costly fixes to HVAC, green roofs, sun-shading and other problems.

- Was confined to mostly commercial buildings at the beginning even though it is expanding its reach to residential construction, core and shell, and neighborhood development.
- Unresolved issues related to use of PVC and wood certification systems.
- Proceeding too slowly and not making a substantial difference in energy savings or other worthwhile attributes when compared to other energy saving systems in use by U.S. Department of Energy Building America program.
- Mediocre green buildings as a result of certification and not environmental responsibility becoming the primary goal.
- A few super-high-level eco-structures built by the highly motivated construction owners standing like targets impossible to attain.
- An increase in the number of LEED-accredited architects and engineers chasing lots of money but designing few buildings,
- An increasing group of building construction stake holders who want to build green but cannot afford the certification.
- Despite reports to the effect that green buildings and the LEED certification process does not cost anymore than conventional buildings, the fact that LEED certification adds 1~5 % to costs has surprised construction owners,
- LEED certification uses funds that could have been used to import worthwhile improvements such as photovoltaic systems, day-lighting, or energy efficiency upgrades,
- A number of criteria that have been awarded the same number of points (i.e. weight) as several others contribute very differently to the bottom line environmental benefits,
- Points trading, i.e. getting points towards certification irrespective of adding to the environmental benefits.
- The need to make some of the fundamental issues coupled to mandatory points that need to be earned.
- The need to integrate the industry groups in the process to entertain their opinions in the design and development of the assessment processes since they are involved in diverse aspects of design and construction.

USGBC has taken note and is trying to address the issues. Nevertheless, other organizations and methodologies such as the North American Coalition for Green Building and the Green Building Initiative of NAHB have emerged with their own systems to cover the LEED shortcomings, to cover the kinds of construction LEED did not cover at the beginning, or to oppose the ways LEED is implemented.

Where and How to Start Integrating the Concepts into Construction Education?

Depending on the type of program in terms of the degree it leads to, the number of years, accreditation, etc., the above concepts can be integrated into the curriculum in different ways. We have tried all of these with varying degrees of success.

- An independent course in “green” and/or sustainability or some course under a similar title if the number of credits in the program allow it.
- If program requires an elective, a green course can be targeted to fulfill this slot. The independent course we offered was also targeted to fulfill the elective requirement in mechanical and electrical +computer engineering programs with varying degrees of acceptance.
- If the construction program entails a course in mechanical systems in buildings or electrical systems in buildings or a combination, which mostly is the case these days, appropriate material can be integrated into these courses with ease in terms of the topics they inherently entail. Some possible avenues are as follows:
    - One is able to cover the issues related to levels of insulation in different parts of a construction and the resultant costs and life-time savings as a consequence. For example a sample class exercise is increasing the size of outside wall studs from 2”x4” studs to 2”x6” studs. This will entail some increase in material cost (costs are available from hardware stores or their fliers to students) but almost no increase in labor costs. This way one is able to increase the insulation by 50% thus leading to significant energy savings over time.
    - Since such a course entails heating and cooling load calculations, students are able to put the annual savings in perspective on a monetary basis. Energy costs for gas, electric, and oil are available in utility bills and this enables students to make calculations for their own homes in terms of the fuel they use and compare it to other fuels. Although this may not be the proper time one can go into the discussion of payback period and break-even at this point also. Same approach can be used for insulation levels in the attic. Increasing the amount of insulation by 100% or more with corresponding increases in material costs can be shown to be very feasible with the significant yearly savings that results from such an undertaking.
    - Research has indicated that the relation between cost (cost of insulation, cost of labor, and cost of energy) versus the level of insulation has a upward “V” shape that has at least a theoretical minima. Consequently it can be explained that for each building component one is able to find the “optimal” level of insulation in terms of insulation and energy and labor costs at the time. An application of the “sensitivity analysis” is also possible in terms of variance of all these parameters governing the situation.

    - One can easily extend these points to include aspects related to windows and whether they need to be single pane, or double pane, or triple pane etc in view of green approaches and lifetime energy savings and determine, again, in terms of heating and cooling load calculations, what the payback periods will be in terms of current energy and window costs (again installation labor costs do not differ much between windows with different number of panes).
    - Heat Island effects on heating and cooling is another topic that finds emphasis in this kind of a course.
    - Different means of heating and cooling of buildings is an inherent topic in this type of a course allowing one to go into solar heating and cooling, geothermal systems, etc with details about their energy saving features, as well as, initial and life-cycle costs.
- Another course which is very conducive to integration of some of the appropriate topics is Engineering Economics if the program entails such a course. The topics in engineering economics related to cost and savings, as well as, life-cycle costing provide a very good fit for coverage of some of the "green" issues and energy savings. Some application examples employed has been as follows;
    - During coverage of analysis of projects using the Annual Cost or Benefit Method, one is able to cover the fundamental applications of the Life-time Costing approach that finds extensive use in green undertakings.
    - During coverage of the Break-even Analysis and Payback Period Analysis one is able to tackle the issue of how increased costs due to green or CN or sustainable undertakings related to projects, if any, will be recovered in terms of energy savings or other quality of life considerations over the life of the project and how long the payback period will be.
    - Considering the fact that green issues come into or go out of favor, without the absence of any mandates, in parallel with energy costs in general, one is able to show, in terms of a "sensitivity analysis" when green begins to make sense, in terms of energy costs and savings, if nothing else, based on energy costs and interest rates in the economy.
- Another course which is very also very conducive to integration of some of the green topics is a Construction Hydraulics and Drainage course if the program entails such a course. Within the context of such a course one is able to touch on the following aspects related to green:
    - Green Roofs and drainage advantages and use possibilities related to such roofs in diverse context. EPA has taken up this topic with serious emphasis so that it is not treated lightly in building design and construction.
    - Building site drainage issues and how they tie to green in terms of complying with EPA requirements related to green.

    - Coverage of use of Pervious Concrete Pavements as a green alternative to traditional drainage methods involving ditches, swales, detention and retention basins etc.
- Yet another place for integration is a capstone course in the program which almost all programs have these days. The capstone course usually entails coverage of an overarching array of contemporary issues in construction into which green concepts fit nicely.

Conclusion

No matter the associated growing pains and problems and complexity in real implementation, venturing into green design and construction and the idea behind LEED has been a worthwhile one. The U.S. is benefiting from these undertakings in the green design and construction arena and it should benefit more from this healthy competition between assessment methodologies and entities. New entrants into the field of assessment of green building and construction will, however, surely make consensus and standards building among these entities more difficult. Still, it is inevitable that in time all such entities will move closer to a mutually acceptable, rational, and practical means of defining green design and construction and its assessment. A culture sensitive to environmentally conscious design and construction is evolving to the benefit of mankind everywhere.

Construction engineering and management programs and other entities venturing into green design and construction and its assessment will be well served by using this overview as a guide as to what to do and what not to do so that some time may be saved during this undertaking which inevitably will have to be done at some point in time considering the realities of our current environment.

Our experience, having tried various ways of integrating green and sustainability concepts into the curriculum in various ways, is that, the best way to do this is not necessarily an independent course, even if the credit hours and other inherent obstacles allowed it, but to integrate the concepts to every single course as much as it is relevant so that the concepts readily find applications in that course whatever may be the level of the course.

Bibliography

1. USGBC web site: www.usgbc.org
2. Ted Smalley Bowen, LEED green-building program confronts critics and growing pains. Main Dish: Constructive Criticism. 26 Oct 2005. http://www.grist.org/news/maindish/2005/10/26/leed/index.html?source=daily
3. Auden Schendler and Randy Utall., LEEDing us astray ? Top green-building system is in desperate need of repair. 26 Oct 2005.http://gristmill.grist.org/story/2005/10/26/1260/6618?source=daily
4. Auden Schendler and Randy Utall., LEED is broken; Let's fix It. 26 Oct 2005. http://www.grist.org/comments/soapbox/2005/10/26/leed/index.html?source=daily.

5. NAHB web site: www.nahb.org
6. The North American Coalition on Green Building web site: (no specific web site but see: http://www.cpia.ca/greenbuilding/, http://www.sourcewatch.org/index.php?title=North_American_Coalition_on_Green_Building and http://www.iswonline.com/wwp/200409/1on10904.cfm
7. Green Globes Emerges to Challenge LEED. What's Happening. Environmental Building News, March 2005.
8. www.sustainable.com.au
9. Jorge A. Vanegas, Jennifer R. DuBose., Annie R. Pearce., Sustainable Technologies for the Building Construction Industry.
10. Godfried Augenbroe, Annie R. Pearce., Charles J. Kibert., Sustainable Construction in the United States of America: A Perspective to the year 2010. CIB-W82 Report, Georgia Institute of Technology, June 1998.
11. Fiona Harvey., Sleek, Stylish, and Sustainable. Financial Times, House and Home, Oct 15-16, 2005, p.1.
12. Jennifer Roberts., When Luxury and Conscience Combine. Financial Times, House and Home, Oct 15-16, 2005, p. 4.
13. Dalia Fahmy., High Rise and High Value from the new Eco-Condo. Financial Times, House and Home, Oct 15-16, 2005, p.4.
14. Holly Yaeger., Designing Our Way Out of Trouble. Financial Times, House and Home, Oct 15-16, 2005, p.8.
15. Alex Frangos., Is It Too Easy Being Green? The Wall Street Journal, Marketplace, Oct 10, 2005, p.B1.
16. Sener, E.M & Baty, P. "Green Design and Construction: An example - Commercial Green Roofs." 2003 American Society for Engineering Education Annual Conference & Exposition, June 2003, Nashville, TN
17. Green Building Initiative web site : http://www.thegbi.org/home/
18. The Green Globes web site: http://www.thegbi.org/commercial/greenglobes/index.htm
19. Environmental Energy Technologies Division, Heat Island Group. (2000). High Temperatures. http://eetd.lbl.gov/HeatIsland/HighTemps/
20. Greeenroofs.com. (2002). Greenroof Concept. <http://www.greenroofs.com/north_america.htm>
21. Lawrence Berkeley National Laboratory. (1998). Reducing Urban Heat Islands to Save Electricity and Reduce Smog. http://www.hr.doe.gov/energy100/communit/71.html
22. Liu, Karen (2002, September). Going Green: A National Research Council Canada study evaluates green roof systems' thermal performances. Professional Roofing, 32 (9), 24-30.
23. Ostrowski, Christopher (2002, March). Green Not Just Environmental Anymore: It's a Money Saver. Midwest Construction, 5 (3), 42-43.
24. Roofscapes, Inc. (2002, July). Role of Green Roofs in Managing Thermal Energy. <http://www.roofmeadow.com>
25. Suttell, Robin (2002, October). Roofing in a Greener World. Buildings, 96 (10), 62-64.

Biography

[1]**Erdogan M. Sener,** Professor of Construction Technology, Purdue School of Engineering & Technology (IUPUI). He earned a BS Civil Eng., Middle East Technical University; MS Civil Eng. Michigan State University. He has over 13 years of international industrial experience in design and construction and has been in engineering and technology education for more than 25 years. Member of ASCE and ASEE and is a registered Professional Engineer. He was awarded numerous teaching awards including the Indiana University President's Award for Distinguished Teaching and the IUPUI Chancellor's Award for Excellence in Teaching, as well as, a number of other department, school, and university awards. He has over 50 papers in journals and conference proceedings.