# INNOVATION TECHNOLOGIES IN GREEN BUILDINGS AND CERTIFICATION

ŞERİFE ÖZATA[1]
ZEHRA CANAN GİRGİN [2]

## ABSTRACT

For a sustainable world, recent awareness depending on the depletion of the Earth's fossil resources and global warming due to high $CO_2$ emissions has impacted building design and construction methods; thereby the green or ecological building concept has emerged. In order to evaluate and categorize green buildings, some evaluation systems were constituted. One of them is accredited LEED certification system (Leadership in Energy and Environmental Design). LEED has silver, gold and platinum certification levels classifying the characteristics of green buildings. In the stages of design, construction and service life, the sustainable building design should satisfy the prerequisites of LEED certification system on sustainable site development, water savings, energy efficiency, materials and resources selection, and indoor environmental quality. The renewable energy sources (wind, solar, geothermal heat pump etc.), efficient lighting, recycling/reuse of resources and materials, and waste recycling should be maximized to ensure the low environmental impact in building technologies. In this study, typical current and innovative technologies in the design of ecological buildings are handled by referring the buildings having LEED certification on different levels.

**Key words**: LEED Certification, Innovative Building Materials, Building Technologies

## 1. INTRODUCTION

In a world with an ever growing population, while energy requirements are increasing, limited resources are diminishing. Renewable energy sources (wind energy, solar energy, biomass energy, geothermal energy, etc.) have minimum impact on environment. Global warming and related depleting non-renewable energy sources (oil, nuclear power, coal, and natural gas) force the scientists to focus on environmentally friendly energy resources. Recycled materials as well as

[1] Res. Asst. Yıldız Technical University, Faculty of Architecture, ISTANBUL
[2] Assoc. Prof. Dr. Yıldız Technical University, Faculty of Architecture, ISTANBUL

optimization of water use are other important issues for a global sustainability. Innovative technologies for a sustainable world should be addressed more and more.

The main purpose of this study is to investigate the special features of innovative building technologies (wind and solar energy; heating, ventilating and air conditioning systems; lighting systems; optimized water material use) as well as the certification system of Leadership in Energy and Environmental Design (LEED) to promote sustainable building design.

## 2. GREEN BUILDING CERTIFICATION SYSTEMS AND LEED

Green building has a lighter footprint on environment and comprises the issues such as energy, water, material efficiency and minimum waste in the design, production, operation, maintenance and demolition removal phases in the life cycle. Various green building certifications (DGNB, BREEAM, CASBEE, and LEED) have been used since the end of 20th century.

The LEED environmental certification by U.S. Green Building Council (USGBC) is most popular and reliable protocol used in over 40 countries. USGBC defined four levels for LEED: Certified, Silver, Gold and Platinum. LEED v4 (2013) is the last version (USGBC 2014). However, teams may still register the projects under LEED v3/2009 until June 1, 2015. LEED v3 has 7 categories: Sustainable Sites, Water Efficiency, Energy & Atmosphere, Material&Resources, Indoor and Environmental Quality, Innovation in Design and Regional Priority) over total 100 points. There also have 6 possible points in Innovation in Design and 4 points in Regional Priority.

## 3. FEATURES OF INNOVATIVE BUILDING TECHNOLOGIES

In this section, innovative technologies in green buildings are focused by addressing certificated buildings.

### 3.1. Wind Energy

Wind energy could be converted to mechanical energy through the wind turbine up to the rate 50% (İlkiliç and Türkbay 2010). Worldwide wind turbines installed by the end of 2013 can provide 320 GW and 628 TWh consumptions per year (BP Statistics 2014). This consumption is 2.7 % of global electricity generation. Denmark, Spain, Germany and Portugal are the leading countries in the base on daily wind energy per person (Girgin 2012).

Wind turbines in building are used more and more. Prediction of wind velocity and direction, and orientation of building are important parameters. Two main concepts of wind turbines are under consideration: the horizontal-axis turbines (HAWT) and the vertical-axis wind turbines (VAWT). Three-blade HAWT turbines are popular due to smoother rotational operation and cost efficiency. As a typical example, the massive three-blade 65kW wind turbine on 37 m mast in the site of Alberici

Corporate Headquarters (2005, LEED Platinum) provides 92 MWh as ~20% of annual energy needs [1] (Fig.1a).VAWT system has the advantages such as lower noise / vibration levels, operation ability in lower wind speeds. In addition, this system does not need to be pointed into the wind which is important in urban areas due to highly variable wind direction and local turbulences.
In addition to wind farms, to design wind turbines in urban areas becomes popular in middle-rise buildings. Mast mounted turbines on the roof (Fig.1b, c) maybe seems to be a cost effective solution but not a very aesthetical solution. The connection of two buildings with wind turbines in Bahrain (World Trade Center, 2008), building integrated five-blades wind turbine in London (Strata Building, 2010), and finally mounting wind turbines into tunnels through a tall building in China (Pearl River Tower, 2012) are pioneering solutions (Fig.2). 225-kW three turbines in Bahrain World Trade Center satisfy 11-15 % of total energy demand, that this quantity (~1200 MWh) is equivalent to lighting of 300 homes per year [2], in the 4-20 m/s operation limits of wind velocity [3].

Integration with building involves complex design techniques due to high aerodynamic noise levels, radio/TV interference due to electro-magnetic forces and the vibration which necessitates damped bearings to isolate building. RC structure option and to install VAWT to mechanics floor may give suitable solution.

Cost and energy efficient turbines with less noise and vibration levels as well as integration with architecture become the main issues. Façade integration, double roof or funneling concepts through Venturi effect [4] are new ideas for building architecture as well (Fig.3a, b).

**3.2. Photovoltaic Systems**

Current worldwide photovoltaic power (PV) capacity is 140 GW, i.e. 125 TWh (2013) (BP Statistics 2014) corresponds to only 0.5 % of global electricity generation. Germany is the leading country in the base on daytime solar energy per person (Girgin 2012).

Photovoltaic materials include silicon, gallium arsenide, copper indium diselenide, cadmium telluride, indium phosphide etc. PV cell can be a mono-crystalline, multicrystalline or amorphous (Kalogirou 2014). Solar cells are mainly categorized into three different types. Inorganic solar cells are first generation, organic solar cells (OSCs) and dye-sensitized solar cells (DSCs) are second generation and hybrid solar cells (HSCs) based on nanostructures are considered for third generation. The power conversion efficiency of first and second generation solar cells were ~25% (silicon) and ~20% (copper indium gallium di-selenide) at lab scale (Babu et al. 2014). Copper Indium Gallium Selenide (CIGS) PVs are a promising technology with moderate efficiency, low cost and light weight characteristics for rooftop installations both in residential and commercial buildings. It is expected nano cells to be commercially available within the next few years, by tremendously reducing cost.

Building-integrated photovoltaics (BIPV) either in the façade and/or roof of the building are the typical application of PVs (Fig.4a, b, c). To prevent additional thermal load and efficiency loss, a gap is created between the PV and the building element (brick, slab, etc.) for air circulation. PVs are recently used on external automated shading system moving around on tracks (Fig.4d, e).

In PV systems, generator is used for deep charge the batteries a few times annually to extend their lifespan or to charge the batteries dropped below a critical ratio (e.g. 20%).

If the construction site is not near electricity lines, a zero energy building can be designed as off-grid system; e.g. Audubon Center, LA (LEED Platinum) gain 110.5% energy (demand is 55 kWh/$m^2$ per year) via roof- mount via 25-kW polycrystalline off-grid PV system (Gevorkian 2008). Energy need of the building can be provided by battery cells during four or five winter days without direct sun light.

### 3.3. Heating, Ventilating and Air Conditioning (HVAC) Systems

Automatically operable windows by monitoring outside weather conditions, carbon dioxide ($CO_2$) monitors to adjust necessary airflow levels throughout the building, under floor air-distribution system supplying air at the level of the occupants are the some characteristics of green buildings.
Blocking north face of building with masonry walls is a good and well known way to save indoor heat. Double façade helps the building maintain its thermal conditions by trapping heat that is radiated from the building and blocking solar heat. Reflective surfaces are used to reduce heat absorption and cool the air.
Low-grade waste steam from neighboring cogeneration plant can be exchanged to heat or used to drive chiller for cooling instead of electricity to reduce energy costs.
Orienting wind through funnel (Venturi effect) by flowing toward open atria on the roof is another innovative method for ventilation (Siemens HQ, Masdar City, LEED Platinum, 2014) (Fig.3a, b).
Temperature and humidity monitors maintain optimal thermal comfort, indoor reflective pond and plants also regulate humidity levels naturally. In addition to outdoor green walls as well as green roofs are organized to reduce heat gain and loss in building. 20 m living wall of atrium in La Maison Du Développement (LEED Platinum, 2013) (Lagace 2014) is a special example to indoor applications (Fig.5b).
Geothermal wells are installed underneath the building (e.g. Clock Shadow Building, 2012, LEED Platinum) to efficiently remove heat from the building. In La Maison Du Développement (LEED Platinum, 2013) on the total area of 6350 $m^2$, 28 geothermal wells (14 kW) were drilled down to 152 m to satisfy nearly 100% of the heating and cooling requirements via geothermal energy (Lagace 2014). Siemens HQ (2014) has the deepest one of 2.5 km [5].

Pond with aquathermal heat pump system can be used for heating during the winter and cooling in the hot summer. 37 % reduction in energy cost was predicted in Saginaw Valley State University (2008, LEED Silver) over 5 ha manmade pond (Thompson and Kerbelis 2013).

Combined heat and power system (CHP) (SUNY-ESF's Gateway Center, LEED Platinum, 2014), is a new alternative to provide steam and electricity in green buildings due to minimal waste output and efficiency twice according to traditional technology by using biomass in addition to other energy sources well [6].

In the near future, it is thought that a technology called "Enhanced Geothermal Systems" would be attainable that involves drilling at least down to 10 km in a similar way to oil exploration techniques [7].

### 3.4. Lighting Systems

South-facing rooms for daylighting, blocking west-facing windows via masonry wall are known solutions. Work places can have almost fully natural lighting. Computer controlled shades and louvers optimize the amount of daylight brought in and prevent glare (Fig.4d, e and Fig.6a, b) in ecological buildings. Innovative shielding system in Al Bahar Towers requires less artificial lighting and 50% less air conditioning (Fig.6c).

Roof mounted mirrors, heliostats, fiber optic system directing the daylight into the building through skylight and sun pipe system delivering daylight up to 14-story (Fig.7a, b). Tertiary mirrors are typical natural lighting techniques nowadays (Fig.8a). The reflective pool in the atrium or the reflective panels on atrium walls are light distributing mechanisms as well. Milled acrylic prisms can be used to enhance reflection, diffuse light, prevent heat absorption and eliminate glare due to halogen lights at night (Genzyme Center, LEED Platinum, 2003) (Fig.8b).

### 3.5 Material Usage and Impact on Environment

It is a well-known reality that the cement sector is responsible for ~7% of global $CO_2$ emissions. In order to decrease this emission in huge construction sector, innovative techniques such as to change the raw material $CaCO_3$ with $MgCO_3$ or to produce concrete without cement via 100 % fly ash are under development. In view of structural systems, the embodied carbon emission to ultimate strength ratios (Fig.9) (Kuruscu and Girgin, 2014) reveal the importance of recycled material utilization instead of virgin one (e.g. steel, aluminum) as well as green concrete and masonry blocks by partially replacing cement with waste by-products such as fly ash, blast furnace slag, rice husk ash etc. Recycled aggregate usage, to put waste tire pieces as aggregate into concrete, to apply $CO_2$ cure to masonry blocks (Fig.10) and to use chemicals absorbing emissions in concrete decrease environmental impact. Some applications such as illuminating concrete and translucent concrete provide aesthetical solutions to save lighting energy in indoor and outdoor applications (Fig.11).

Wooden composite structures from renewable and certified forests are currently being constructed to reduce $CO_2$ footprint more and more. Formaldehyde-free glues and paints in wooden composites are used to prevent health problems in humans (Fig.12).

Building materials from local sources in high ratios and water-based finishers reduce impact on environment. Nearly total waste of construction or demolition should be diverted to landfill, reuse, donate or recycle.

Green roof by planting an insulated roof membrane assembly (IRMA) is a wide spread application in green buildings. Moisture sensors installed in the soil (inside and outside) is a good solution to eliminate unnecessary watering (Fig.13a). In Alberici Corporate Headquarters won the highest LEED rating (60 over 69 credits in six categories in 2004), rainwater from the garage roof is collected in retention ponds and used in the building's cooling tower and sewage conveyance system (Fig.13b). Thus, less water consumption up to % 70 is possible via rainwater collection and other preventions.

## 4. CONCLUSION

Innovative technologies progress toward min. energy requirement and almost full usage of recycled/reusable materials in buildings. Zero-energy building, 70 % less water consumption, ecofriendly recycled/reusable material in high ratios, 100 % lighting of work places are possible in current green buildings certified by LEED.

Renewable energy technologies such as solar panels, geothermal wells, wind turbines are under progress. Although initial capital cost in green buildings is relatively high, especially lifetime energy expenses are less compared with conventional buildings. However, sustainable buildings should not be designed not only to be registered by LEED but also should be affordable for common housing by people as well. It is suggested that the credit in LEED for Innovation in Design can be encouraged with higher points than current 6 points to provide the development and use of innovative technologies.

### 4.1. Figures, Graphics, Photographs and Tables

a. b. c.

Figure 1: a. Alberici Corporate Headquarters (USA, 2005), b. Hafencity (Germany, 2014), c.Twelve West (USA, 2009) c. [8, 9]


Figure 2: a. Bahrain World Trade Center (Bahrain, 2008), b. Strata Tower (London, 2010), c. Pearl River Tower (China, 2012) [10-13]

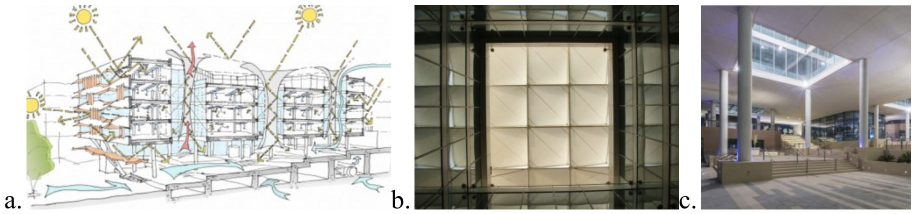



Figure 3: a. Sketch of ventilation and Venturi effect in Siemens HQ (UAE, 2013), b. Orientation of voids for Venturi effect, c. A typical exterior shaft [14, 15]

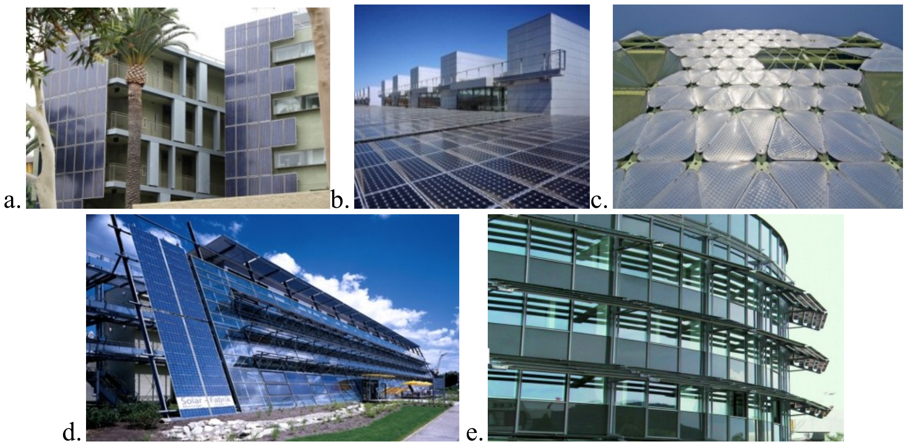



Figure 4: Building-integrated photovoltaics (BIPV) in the façade and roof [16-20] :

a. Colorado Court (USA, 2002), b. Water and Life Museum (USA, 2007), c. Media-ICT Building, (Spain, 2011), d. Solar Fabrik Headquarters (Germany, 2005), e. Shadovoltaic panels


Figure 5: a. Green roof of the Vancouver Convention Center (Canada, 2009), b. Atrium with living wall [21, 22]

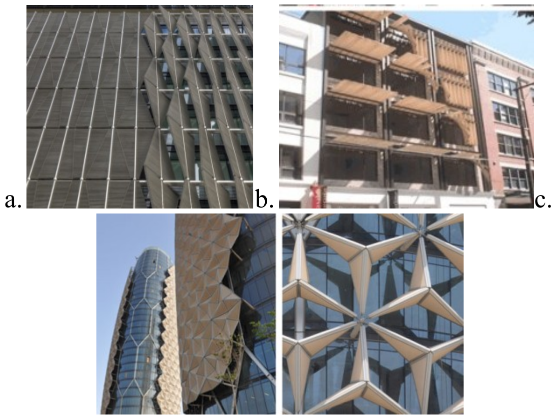



Figure 6: Computerized panels : a. Kinetic façade b. ThyssenKrupp Quarter Essen Building (Germany, 2010) façade, [23-25], c. Al Bahar Tower, overall view from the north and folded panel view

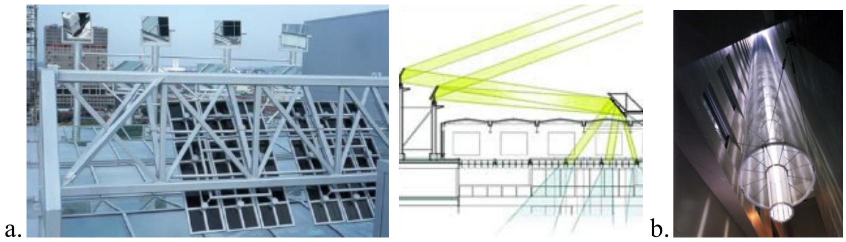



Figure 7: a.Roof mounted mirrors (heliostats) directing sunlight into the building through a skylight, b. A 14-storey height sun pipe [26, Mayhoub 2014]

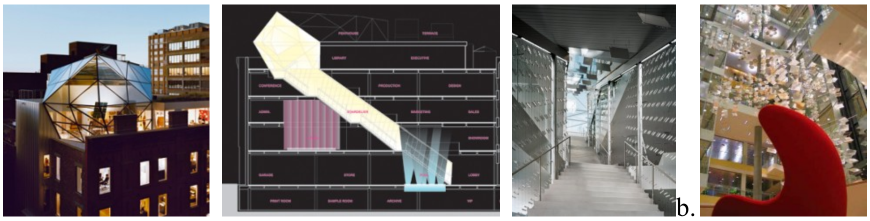
a.  b.

Figure 8: a. Tertiary reflective mirrors (Diane von Furstenberg (DVF) Studio-USA, 2007), b. Milled acrylic prisms in Genzyme Center (USA, 2003) [27, 28]

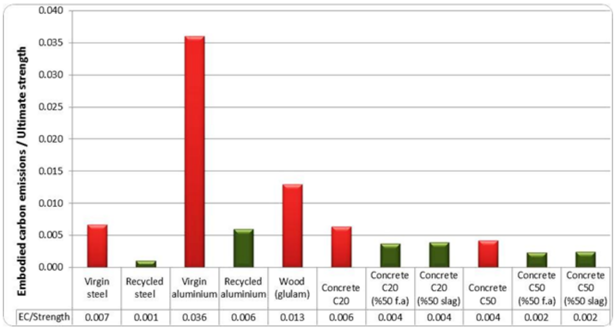



Figure 9: Embodied carbon emissions to strength ratios in structural materials (Kuruscu and Girgin 2014)

a.  b. c.

Figure 10: a.Recycled aggregates, b. Concrete with rubber pieces, c. $CO_2$ cured concrete masonry blocks [29-31]

a.  b.  c.

Figure 11: a. Illuminating concrete pathway, b. Transcluency in Fairholme Capital HQ (USA) and Les Turbulances-Frac Center (France, 2013) [32-34]

a.  b.  c.

Figure 12: a. Certified forests, b. A typical wooden composite structure (Olympic Oval, Canada, 2008), c. Formaldehyde-free painting [35-37]

a.  b. 

Figure 13: a. Moisture sensor b. Alberici Center Headquarters and rainwater pool [38, 39]

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