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Sustainable Construction, LEED as a Green Rating System and the Importance of Moving to NZEB

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Abstract. In this study, in order to evaluate the possibility of achieving the Net Zero Energy Building (NZEB) goal, the history of sustainable construction, and available green-rating systems with specific focus on Leadership in Energy & Environmental Design (LEED) rating system were explained. LEED rating system was selected as the most prevalent rating system in the industry to evaluate and analyze its efficiencies/drawbacks specifically in regards to the energy efficiency. The goal of this study is to answer an important question of the reasons to focus on NZEB concept when LEED rating has come up with a detailed certification process, which is somehow beneficial in regards to energy reduction. NZEB concept is defined as an evolution of very energy-efficient approach and it requires that the buildings have zero energy balance on an annual basis. This paper explains this questions in detail and it consists of three parts: in the first part sustainable building rating system including LEED certification is explained. The second part explains the deficiencies of LEED rating system in regards to the energy performance of buildings and the last part explains the NZEB concept and the movement towards the NZEB target.

1 Introduction

The increasing attention to sustainability is pushing the construction sector towards rapid changes where policies, laws and regulations around the world demanding the need to adopt sustainable innovation in terms of products and processes to encourage more sustainable buildings [1]. Sustainable buildings have been broadly defined as buildings that encompass environmental, social and economic standards [2].

After the energy crisis in the 1970s, regulations promoted energy consumption limits for buildings around the world. As a result, energy consumption evaluation became the sustainability measure for building assessment. Meanwhile, sustainability consciousness has evolved and in the current industry trends, energy consumption is generally considered as just one among other parameters where the complexity of a building often suggests a multidisciplinary approach in sustainability assessment [3]. Therefore, the sustainability of a building should be evaluated for every subcomponent (e.g. the air conditioning system, the envelope, etc.) as well as for the building in its entirety and in relation to the surrounding environment. According to Intergovernmental Panel on Climate Change [4], the building sector with sustainable features has the highest energy saving potential, however without ratings system, the recognition of sustainable buildings is often unclear where measurement of sustainability is a frequent discussion topic among AEC team members [1].

In the AEC industry, several multi-criterion systems exist to assess building sustainability worldwide where most of them are just adaptations of one system with modification according to the specific local region. The most popular rating systems are BREEAM, LEED, CASBEE, Green Globes, Australian Building Greenhouse Rating (ABGR), the US Assessment and Rating System (STARS) and the South African Sustainable Building Assessment Tool (SBAT).

As the concerns toward climate change and global warming increase, the development of building environmental assessment methods within many individual countries domestic market has risen drastically where Building Research Establishment Environmental Assessment Methodology (BREEAM) of the UK, Green Building Council of Australia (GBCA) and Comprehensive Assessment System for Built Environment Efficiency (CASBEE) for the Japan market are some examples of green codes around the world [5].

BREEAM is the first multi-criterion system for sustainability assessment where it was planned at the beginning of the 1990s by the British Research Establishment (BRE) and then released in 1993. The system has a large diffusion in the United Kingdom, where almost 10,000 buildings have been certified. Since 2009, as a consequence of the worldwide attention garnered by this system, an international version has been released, and currently BREEAM has adapted versions for Canada, Australia and Hong Kong. Despite the success of BREEAM, a widely spreading sustainability rating system is LEED (Leadership in Energy and Environmental Design), which was released in 1998 by the US Green Building Council (GBC) and although it was released in the US, GBC has been diffused

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worldwide over the years, and recently the World GBC has opened regional chapters in countries in Europe, Africa, America and Asia. Almost 20,000 buildings are registered for certifications, and current requests for new certifications regard buildings in 110 countries.

Similarly in the US, the need over energy independence and sustainable environment, has forced the architecture, engineering and construction (AEC) industry in the development of some prominent solutions, practices and theories in this regard to increase energy efficiency and reduce energy consumption. The International Green Construction Code (IgCC), American Society for Heating, Ventilation and Air-conditioning Engineers (ASHRAE) Standard 90.1, Energy Star, United States Green Building Council (USGBC), Leadership in Energy and Environment Design (LEED) and the most recent standard, Net Zero Energy Building (NZEB) as a certification path under the Living Building Challenge (LBC) presenting an evolution of very energy-efficient buildings requiring the buildings to have zero energy balance on an annual basis, are examples of energy codes in the US as depicted in [6].

Even though the above-mentioned ratings and standards could battle climate change, resource depletion and environmental damages, they still need to be embraced by society and individuals before they can become effective solutions.

2 LEED rating system

LEED as one of the most established codes in the US and also another countries is a green building certification system developed by United States Green Building Council (USGBC) which encourages a building or community to be designed with consideration of environmental impact, energy savings, and human comfort [7, 8].

A LEED rating rewards designers for using strategies that can improve performance in metrics such as CO_2 emissions reduction, water efficiency, energy savings, indoor environmental quality, and other environmental impacts. Although LEED does not guarantee a specific energy performance of a building or community, it is one method to help towards this goal [9].

According to United States Green Building Council [10], the LEED system initially supported certification for only new construction (LEED-NC), however, the existing buildings and commercial interior certifications were added in 2004 and core/shell certification was added in 2007. LEED rating system provided flexibility for earning points toward certification by initially crediting in several categories such as: 1) sustainable sites; 2) water efficiency; 3) energy and atmosphere; 4) materials and resources; 5) indoor environmental quality and 6) innovation and design process. Also, there are four levels of certification as a) Certified; b) Silver; c) Gold, and d) Platinum.

The pilot version of LEED rating system was launched on 1998 and then USGBC began to modify the LEED system where between the years of 2000 to 2005, newer LEED versions as LEED 2.0, LEED 2.1 and LEED 2.2 were introduced to the building industry. According to [11] during the early years of LEED introduction, it was possible to earn a Platinum rating without earning any points in the ‘’Energy and Atmosphere’’ category, however, to fix this issue, the USGBC developed the requirement of a minimum of two points in the ‘’Energy and Atmosphere’’ credit category for any buildings certified after June 2007.

After the early versions of LEED rating system, on the year of 2009, LEED V2009 or sometimes referred to as LEED V3, was published where in LEED V2009, the number of possible points available in the various credit areas had increased and the number of points required for the four certification levels had been adjusted accordingly (Table 1). Also, starting with LEED V2009, all LEED certified buildings were required to report energy consumption. Finally, during November 2013, LEED-NC V4 was introduced as the latest version with some modification to sustainable site credit where it was divided to two categories, adding the location and transportation category, along with integrative process (Table 2).

Table 1. LEED- NC, Max Points Awarded By Credit Category & Version

Credit Category	V2.2	V2009	V4
Location & Transportation			16
Sustainable Site	14	26	10
Water Efficiency	5	10	11
Energy & Atmosphere	17	35	33
Materials & Resources	13	14	13
Indoor Environmental Quality	15	15	16
Innovation & Design Process	5	6	6
Regional Priority		4	4
Integrative Process			1
Total Base Points	**69**	**100-110**	**110**

Table 2. LEED- NC Point Range for Certification Levels by Version

Certification Level	V2.2	V2009	V4
Certified	26-32	40-49	40-49
Silver	33-38	50-59	50-59
Gold	39-51	60-79	60-79
Platinum	52-69	80 or above	80 or above

3 Issues with LEED rating system

LEED certification is a very good step in order to incentivize reduction in energy consumption. However, as per the 2008 report on 'Energy Performance of LEED for New Construction Buildings', one quarter of the LEED certified buildings use much more energy than their proposed usage. Some of the buildings even use more energy than the code baseline itself [12]. The same report illustrates that the buildings with LEED platinum rating barely meet the proposed saving mark and even a few of the buildings among platinum rated are using more energy than the code baseline.

In a research by [1], an analysis of measured energy-use data from 100 LEED certified buildings yielded that on average LEED buildings use 18– 39% less energy per floor area. However in the same year, another study by [4] showed that 28– 35% of LEED buildings use more energy than buildings without a LEED certification. Further, this study clarified no statistically significant relationship between LEED certification level and energy use intensity or percentage of saved energy in comparison to conventional buildings. In other words, LEED Silver buildings did not exhibit better energy performance than LEED-certified buildings or LEED Gold/Platinum buildings did not exhibit better energy performance than LEED Silver buildings.

4 Issues with LEED rating system

Considering the importance of obtaining points under ''Energy and Atmosphere'' credit category under LEED V2009 and latest version (LEED V4), in this section, the main modification in the credit assignment methodology and modified standards are explained and compared between these two versions (Table 3).

The Energy and Atmosphere in LEED V4, continues to be the most comprehensive section in terms of points a project can earn credit category and is similar in structure to the LEED 2009 where it still addresses commissioning, refrigerant management, minimum and optimized energy performance, green power and renewable energy, however, there are some modifications in comparison to older version (LEED 2009) as following [13]:

EA Prerequisite 1: Fundamental Commissioning and Verification. Formerly "Fundamental Commissioning of Building Energy Systems," this prerequisite was modified in order to cover the following items:

- Indoor-environmental-systems quality and durability;
- Operation and maintenance plan to document building-operations sequence, occupancy schedule, equipment run time, HVAC/temperature set-point, preventive maintenance plan, and periodic commissioning plan;
- Qualified third-party commissioning authority (CxA) for projects exceeding 20,000 ft2 in comparison to 50,000 ft2 under LEED 2009;

EA Prerequisite 2: Minimum Energy Performance/EA Credit 1: Optimize Energy Performance:

- Prerequisite 2 requires projects to meet the mandatory provisions of ANSI/ASHRAE/IESNA Standard 90.1, Energy Standard for Buildings where the reference standard has changed from 2007 to 2010 version of ANSI/ASHRAE/IESNA Standard 90.1. Therefore, the project energy performance is compared to an ASHRAE 90.1-2010 baseline building, which is an average of 18 percent more efficient than the LEED 2009 baseline of ASHRAE 90.1-2007, according to the U.S. Department of Energy (DoE).

EA Prerequisite 3: Building Level Energy Metering:

- As a new prerequisite, it requires building-level metering system to be aggregated for electricity, natural gas, fuel oil, steam, chilled water and biomass where the metered data must be shared with the USGBC for five years following occupancy or certification, whichever comes first;
- Energy consumption must be tracked at one-month intervals and energy data must be shared for five years or until the building owner or lessee changes.

EA Prerequisite 4: Fundamental Refrigerant Management/EA Credit 5: Enhanced Refrigerant Management:

- The purpose of EA Credit 5 is to reduce ozone depletion through enhanced refrigerant management where option 1 (no refrigerant or refrigerant with an ozone-depletion potential of 0 and a global-warming potential of less than 50) and option 2 (environmentally safe refrigerants) have not changed in comparison to LEED 2009. However, the guidelines addressing the use and monitoring of non-ozone-depleting refrigerants have been added for commercial refrigeration systems.

EA Credit: Advanced Energy Metering:

- This credit offers an approach to monitoring whole-building systems or any system-level unit representing 10 percent or more of annual energy consumption. Meters are to record demand and consumption at least once an hour and data are collected automatically and transmitted to a remote location for storage for at least 36 months.

EA Credit: Enhanced Commissioning:

- For this credit, the points have increased from two to six.

EA Credit: Green Power and Carbon Offsets:

- According to [14], the goal of the Green Power Credit is to support the growth of clean energy and LEED V4 has new requirements to achieve Green Power Credits and some of them are likely to have a great impact on LEED project developers and the renewable energy industry where the requirements are more stringent than LEED 2009 versions.
- Under LEED v4 projects must commit to green power for a minimum of five years (as opposed to two years in LEED 2009), to be delivered annually where it gives the green power developers more long-term demand certainty.

Table 3. Comparison of LEED V4 vs. LEED 2009

	LEED V4	Credits	Notes	LEED V2009	Credits	Notes
Prereq 1	Fundamental commissioning and verification	Required		Fundamental commissioning of building energy systems	Required	
Prereq 2	Minimum energy performance	Required	References ASHRAE 90.1-2010	Minimum energy performance	Required	References ASHRAE 90.1- 2007
Prereq 3	Building-level energy metering	Required		Fundamental refrigerant management	Required	
Prereq 4	Fundamental refrigerant management	Required		N/A		
Credit 1	Enhanced commissioning	6		Optimize energy performance	1 to 19	
Credit 2	Optimize energy performance	18		On-site renewable energy	1 to 7	
Credit 3	Advanced energy metering	1	Install building level energy meters and share data with USGBC for 5 years	Enhanced commissioning	2	N/A
Credit 4	Demand response	2		Enhanced refrigerant management	2	
Credit 5	Renewable energy production	3		Measurement & verification	3	
Credit 6	Enhanced refrigerant management	1		Green power	2	
Credit 7	Green power and carbon offsets	2	Purchase green power for 50% or 100% of building total energy for 5 years	N/A		Purchase green power for 35% of building electricity use for 2 years
Possible points	33			35		

5 Necessity to move towards net-zero energy buildings

As it was mentioned in the earlier section, the construction industry has been riding a wave of green building over the past 15-20 years. LEED, Green Globes, or LEED equivalent buildings are now standard practice systems in many markets and required by policy in others [15]. Design firms, owners, operators and occupants are all familiar with the term 'green' building, although they may define it differently and the "green" building trend has accelerated the expectation and adoption of energy efficient technologies. Despite the growth, available rating systems, only covers stringent energy regulation in the design and construction phase and therefore new leader in energy efficient buildings is required to emerge. Net-Zero Energy (NZE) standard which has captured the attention and engagement of practitioners in design, construction, real estate, and policy has the possibility to assess building performance not just in design and construction but also once in the operation phase.

The largest study of NZE buildings in North America was conducted by NBI documenting the growth and the trends of NZE buildings striving to become net zero [15]. The study reveals that even though the number of NZE buildings remains small in current market as a proportion of overall commercial floor space, it is trending upward as building energy use remains the single greatest contributor to carbon emissions in the U.S [16].

6 The net zero energy (NZE) concept

The term of net-zero energy homes is relatively new but the general movement toward low-emission/energy homes started with solar passive house movements in the mid 20th century. There were approximately thirteen solar heated building completed before 1960 in the United States [17]. Those projects were the first generations of low-energy demand homes in the modern era. MIT Solar House I [18] is the first project built in 1939. This two-room laboratory building was used to support developing methods to calculate the performance of the very first blackened copper solar collectors. The early solar houses of this era were mostly houses with large picture windows facing south. By the mid 1970s the number of solar houses increased and a common goal in design process of these projects was experimenting and improving solar energy with low technology approaches. The general believe of that time was that the simple technology would be efficient, reliable, and less disruptive to the environment [18]. Odeillo Residences (1974), Tyrrel House, The Hofman House, and Baer House (1972) are good examples of that period in the US. The combination of concrete wall with attached greenhouse in Hofman House and the water walls of Baer House are good examples of the 1970s approach to build solar houses and energy harvesting from renewable sources. The major setback with the simple technology was lack of proper control in heat distribution and management.

In the past decade while many experimental and practical energy-neutral buildings have been built across the US and around the world, obstacles blocking the integration of the concept into mainstream building types remain.

Before the concept of NZEB emerged, a great portion of research focused on the energy efficiency of single buildings. Some goals and objectives of building energy efficiency have been posted by governmental and professional organizations, as follows:

In 2007, Energy Independence and Security Act (EISA) authorized the Net-Zero Energy Commercial Building Initiative with a series of specific objectives for the development of zero energy commercial buildings, including:

1. All new commercial buildings reach the goal of net zero energy by the year of 2030;
2. 50% of U.S. commercial buildings reach the goal of net zero energy by the year of 2040;
3. All U.S. commercial buildings reach the goal of net zero energy by the year of 2050.

Also, the “2030 Challenge” adapted by the American Institute of Architects (AIA) in 2009 advocated promoting energy efficiency with a goal that, to the year of 2030, all existing buildings will reduce energy consumption by 50 percent of current consumption, and all new constructed buildings will be carbon free. In Europe, all new buildings in European Union member states are required to produce as much on site energy as they consume before the end of 2020. There are some other similar goals and objectives proposed by various groups to reach the goal of NZEBs.

7 Definition of NZE

There are several definitions for a NZEB and each definition differs depending on the boundary and metric used to define the building. A NZEB is ideally a building that through high efficiency gains can meet the rest of its energy needs through renewable technologies. Zero is the point where the building generates energy and its consumption is none or the sum of the energy flows in equals the sum of the energy flows out.

ASHRAE defines NZEB as “A building which, on an annual basis, uses no more energy than is provided by the building’s on-site renewable energy sources’’. National Renewable Energy Laboratory (NREL) defines it, as “A residential or commercial building with greatly reduced energy needs through efficiency gains such that the balance of energy needs can be supplied with renewable technologies”. The US Department of Energy (DoE) states as: “A building that produces and exports at least as much emissions-free renewable energy as it imports and uses from emission-producing energy sources annually’’ and the International Energy Agency (IEA) defines as ‘’a building that remains neutral over a year by getting all of its required energy from solar and other renewable energy sources instead of fossil fuels [19] with delivering as much energy to the supply grid as using from the grid’’ [20].

According to the research by the New Buildings Institute (NBI) the terms to determine a NZE building are categorized in the following order

- Net Zero Energy (NZE) Buildings – NZE buildings have greatly reduced energy loads such that, over a year, 100 percent of the building’s annual energy use can be met with onsite renewable energy.
- Zero – This means ‘’nothing’’ – plain and simple.
- Net – A result from combining more than one item. In this case from energy used in the building and energy produced in the building. If the energy used by the building is completely (or more) replaced by energy produced by renewable sources at the building and/or building site, then the building’s energy use is ‘’net’’ zero. It should be noted that energy use and production are constantly changing so the ‘’net’’ varies widely over the year and because of that ‘’net’’ is calculated as an average over 12 months.
- Energy – Energy means all energy (electric, gas, steam, liquid fuel, etc.) consumed at the building interior and exterior.
- The ABC Equation –Three items are required to calculate net energy: (A - B = C) where (A) is 12 months of Building Energy Use in kBtu/sf/yr, (B) is12 months of Onsite Renewable Production in kBtu/sf/yr and (C) is Annual Net Energy Use Intensity (EUI) in kBtu/sf/yr.
- Energy Use Intensity (EUI) – In order to normalize the various fuels in a building, all the energy forms for both use and production/generation are converted to thousands (k) of British Thermal Units (Btu) and then divided by the square feet (sf) of the building with ‘yr’ representing the 12 month period of data. The EUI is expressed as kBtu/sf/yr and is the most commonly used metric of a building’s energy use or performance. It also allows benchmarking and comparisons of buildings.

NZE Status – NZE can be a goal during design concept, a target set and applied through energy modeling or an actual metered result after 12 or more months of energy data and occupancy.

8 Categories of NZE buildings

In order to distinguish between buildings that are targeting NZE versus those that have accomplished NZE status, NBI has introduced the following terms, which are both applicable to districts or communities (groups of buildings) as well as individual buildings:

• NZE Verified - Documented to have met, over the course of a year, all net energy use through onsite renewables.

• NZE Emerging - Have a publically stated goal of NZE, but do not yet meet the definition of NZE verified. These may be in the planning or design phase, under construction or have been in operation for less than a year. Others may have been operating for 12 months or much longer, but their measured energy has either yet to achieve net zero or the measured data to document verified status was not available.

Low Energy or Near Zero – These buildings are comparable to NZE buildings based on type, energy use, design strategies and technologies but do not have a stated goal of NZE and do not meet all their energy needs with onsite renewables, although they may have renewable resources onsite. In some cases they have provided the structure and wiring that will easily incorporate renewable energy at a later date.

9 Net-Zero energy buildings statistics around the world

More than 200 projects have been identified all around the world with the concept of NZE in the last 20 years where the number of finished buildings has risen continuously per year [21]. The first small NZE residential buildings were built by ecologically enlightened developers and architects and with the progress of efficient technical solutions, bigger and more energy intensive buildings have been built since 1998 [22].

With the rise of energy costs, resource shortage and climate change issues, private building owner alliances, house building societies and architects have implemented the NZE concept to fulfill high performance green buildings. In the US, due to rising energy cost, lower cost of on-site renewable energy and increasing concerns over climate change, interest in NZE has increased over the past few years.

According to [23] the state of California requires all new residential buildings to be NZE by 2020. Studies by [24] show the existence of several NZE homes in the states of Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont.

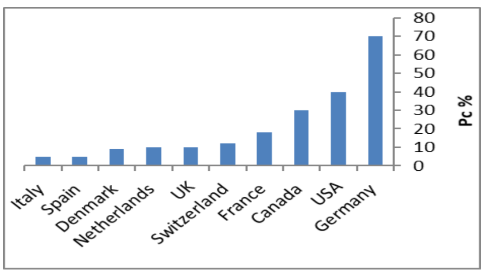

Fig. 1. Number of identified NZE in different countries (Stranger et al. 2007)

10 Trends of NZE buildings in the north-America

Net zero energy is a growing trend that is becoming more attainable financially with the continued advancement and affordability of building technology considering the mandate by cities and states, as well as corporations, foundations, and investment firms to reduce carbon emissions towards mitigating climate change. The construction of NZE buildings as a pathway to lower carbon emissions is already an adopted goal in California, in which new state facilities move to NZE by 2020-2025, and all new and 50 percent of existing, commercial buildings statewide are to be NZE by 2030. Vancouver, British Columbia has likewise adopted a policy to be carbon neutral by 2050. Similar policies for NZE codes are in place or underway in Colorado, Massachusetts, Minnesota, New Mexico, Vermont and Washington as well as many large and small cities across the continent.

According to a recent study by the NBI, the number of buildings at or reaching for NZEB projects have increased from 99 in 2012 to 213 in 2014. Even more promising is the increase in emerging projects with zero energy intentions from 39 in 2012 to 152 in 2015.

However, despite the growth in the number of NZE projects, there are still debates in the industry to find out whether the NZE is the right path for energy efficiency investments or not considering the cost barriers in this extremely new market [25]. However, despite the challenges, research by NBI on 23 buildings in the path to become NZE shows that NZE building is achievable with the consideration of the following patterns in the industry.

1)With a growing set of successful projects to serve as models, design and construction teams are quickly figuring out how to achieve NZE performance while keeping costs in line with other green building projects where all agree that integrated design is fundamental to achieving the necessary energy performance and managing project costs. This process allows all stakeholders—owner, architect, engineer, building manager, etc.—to work together from the start ensuring that building form and function meet the needs of occupants as well as energy performance goals.

2)With the drop in the cost of solar power, the large share of net zero energy verified projects are using photovoltaic (PV) systems to generate onsite energy where according to the research by the Union of Concerned Scientists [26], the prices for rooftop PV systems have fallen almost 29 percent from 2010 to 2013.

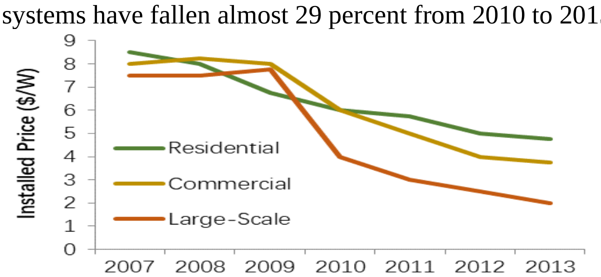

Fig. 2. Drop in the price of solar PV panels in the US, Source: Lawrence Berkley National Lab (LBNL)

11 Discussion and conclusion

Uncertainty in the performance of LEED rated buildings raise the question about their possible deteriorating impact on the occupants health and adverse impact on overall building energy performance [27].

Optimizing the LEED rated facilities, could help in fulfilling the above-mentioned benefits while moving toward to NZEB concept. According to available literature, despite the available cases of NZE buildings in residential sector with the published data of their performance during the operation phase, there is not enough research yet regarding the creation of NZE facilities in a broader scale.

Therefore, the question of assessing the possibility to push the LEED-rated buildings to become a NZEB is demanding specially in other sectors such as commercial or educational facilities. Studies by [28] presented the only 2 certified NZE educational buildings by DOE without having any data of their performance after certification process. In the meantime, the application of renewable technologies such as PV panels has many social benefits alongside financial and environmental savings such as educating the general public by conducting exhibitions, developing creative thoughtful thinking and change in attitude of people towards energy issue where moving toward NZEB could fulfill this goal simultaneously.

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