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A PATH TOWARDS NET ZERO ENERGY BUILDINGS

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ABSTRACT

The environment is one of the most basic public assets of a human system, and it must be therefore specially protected. Sustainable development is understood as a development that does not damage the ecological or social systems on which it depends, but it approves ecological limitation under the economic activity frame and it has full comprehension for support of human needs.

This paper explores the ways to deliver highly efficient buildings whose reduced energy demand is satisfied by clean, renewable energy. Building off of the broader concept of a green or sustainable building, the concept of the "net zero building" focuses on the energy dynamics and performance of the building. And as policymakers and leaders align toward the net zero concepts, the focus on achieving deep energy efficiency has centered on integrated technologies as well as ways to connect buildings to the natural environment.

The paper addresses the importance of sustainable design by reducing or completely avoiding depletion of critical resources like energy, water, and raw materials and prevent environmental degradation caused by facilities and infrastructure throughout their life cycle to make the built environments livable, comfortable, safe, and productive. Buildings use resources (energy, water, raw materials, and etc.), generate waste (occupant, construction and demolition), and emit potentially harmful atmospheric emissions. This is a unique challenge for Building owners, designers, and builders face to meet demands for new and renovated facilities that are accessible, secure, healthy, and productive. The impact on society, the environment, and the economy has to be minimized.

The paper concludes with recommendations to find ways to reduce energy load, increase efficiency, and maximize the use of renewable energy sources in federal facilities. Improving the energy performance of existing buildings is important to increasing our energy independence.Net zero energy buildings is a way to significantly reduce our dependence on fossil fuel-derived energy.

KEYWORDS: Net Zero Energy Buildings, Energy Calculation Methodologies, Energy Efficient Buildings

INTRODUCTION

The concept of Net Zero Energy Buildings (NZEB) has gained importance as well as international attention since the publication of Energy Performance of Building Directive recast in 2010 (EPBD 2010), specially due to rise in the issues like climate change, increasing energy demand, depletion of energy resources, increase in the energy costs, increase in pollution and various such issues. To combat these issues, many countries already have embraced the idea of incorporating 'NZEB' as their future building energy targets. Largely, Net Zero Energy Buildings involve two design strategies – one is to reduce the consumption/need of energy use in the buildings mainly through passive solutions and energy efficient systems and second is to use renewable energy and/or other technologies to meet the required energy

balance. However, designing successful NZEBs is a challenge till date, since the definitions are still broad and there is no standard approach for designing them. The focus of this paper is to understand the concept of Net Zero Energy Buildings through various existing definitions and to understand a variety of existing approaches to calculate the energy balance.

Buildings consume about 40% of energy globally (UNEP) and produce about 33% of greenhouse gas emissions. Also it is generally believed that the climate is changing and there is a growing energy resource shortage. With appropriate use of technology it is anticipated that the energy consumption in building sector can be reduced to about 30% to 80%. A lot of research is ongoing in the sector of net-zero energy building (NZEB) since the inception of the concept to achieve a significant decrease in the energy use in buildings. This concept has become a vital part of energy policy in several countries especially after the recast of the EU directive on energy performance of buildings in 2010. As per the directive, it is targeted that by the end of 2020 all new buildings shall be nearly zero energy buildings. There are a significant number of validation projects as well as research done in this field emphasizing the growing attention given to NZEBs internationally. In spite of this growing interest and research, designing a successful NZEB is still a demanding task mostly due to its definitions being generic. Current international researches mostly focus on establishing a common unambiguous definition and understanding of the concept. Along with this there is also a need of robust calculation methodology to understand how the 'zero' balances is computed. This paper discusses the diversity of existing definitions of NZEBs and aims to underline the most important aspects that play a vital role in each definition. It also discusses various approaches towards existing NZEB

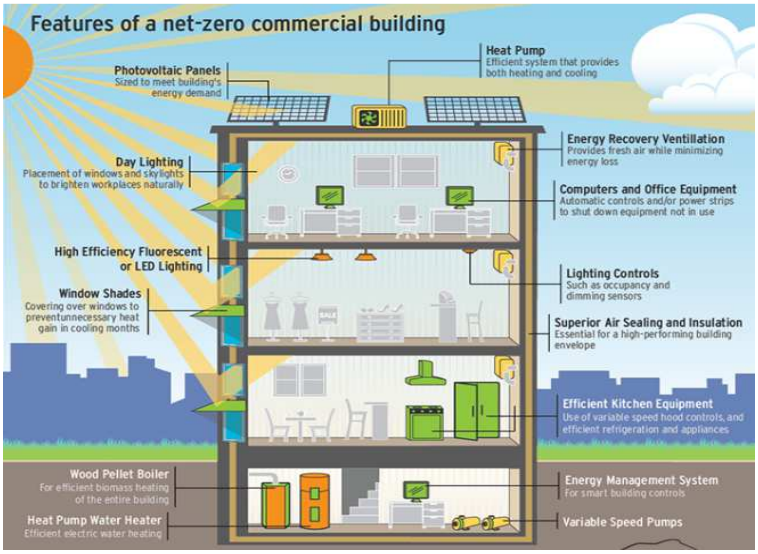

Figure 1

NET ZERO ENERGY BUILDING CONCEPT AND CALCULATION METHODOLOGIES - LITERATURE REVIEW

The overall idea of NZEB appears to be very simple at first; however it is a very complex idea with a number of definitions and approaches. A basic definition of NZEB states that a Net Zero Energy Building is the one that reduces the energy requirement of a building using passive design strategies and energy efficient systems. Also it should be able to generate required electricity by renewable energy sources to meet the remaining energy needs. This two-step concept is the basic approach; however there are other parameters that need to be included in the definition like the following

- The metrics(the unit of calculation)
- The period of the balance (duration of calculation)
- The energy used
- Type of balance
- Alternatives of renewable energy supply
- Possible connection with the energy infrastructure
- Building requirements

The Metrics (A Suitable Metric- Primary Energy, Carbon Emissions Etc)

The unit that is applied towards calculating the 'zero' balance can be affected by a number of aspects suggesting the use of more than one unit for definition as well as for calculation methodology. These could be the primary energy, final energy i.e. delivered, un-weighted energy, emissions equivalent to CO_2, the cost of energy, energy, the goals of the project and the investors and such other aspects. There are disparities in calculating the energy demand globally as different countries use different aspects for the calculation procedure. This results into development of four different definitions, each related to a specific aspect. These are categorized as

- The site ZEB (zero energy building)
- The source ZEB
- The emissions ZEB
- The energy cost ZEB

There are certain advantages as well as disadvantages associated with each definition. It is easy to implement 'zero site energy' and 'zero energy cost' definitions while it is complex to calculate 'zero source energy' and 'zero energy emissions' due to their non-regional features. Researchers suggest that one must address both quantity as well as quality of energy while defining the metric balance of NZEB so as to assess the complete buildings environmental impact. This gives rise to a new definition which talks about the net zero energy buildings. According to this definition the NZEB "is a *building that has a total annual sum of zero energy transfer across the building-district boundary in a district energy system, during any (all) electric transfer taking place in a certain period of time*". The definition obtained from energy performance of building directive (EPBD) clearly favors the primary energy as the metric for energy balance and also studying various methodologies featured in EPBD, one can understand that it is the most preferred metric.

The Period of the Balance

The period of the balance means the time frame over which the building calculation is performed. This can vary from a full life cycle of a building i.e. the life time/ till it is occupied/ operational time of the building approx. 50 years, to the annual balance or even seasonal or monthly balance. The most favored among these time frames is the annual balance. This choice is governed by the following factors -

- Majority of the existing building simulation programs simulate annual energy usage as a final outcome.

- Across ZEB definitions it is the most preferred time frame (11 out of 12 featured methodologies use annual balance).
- Annual balance is the most preferred as it takes into account the variety in energy use due to weather conditions.

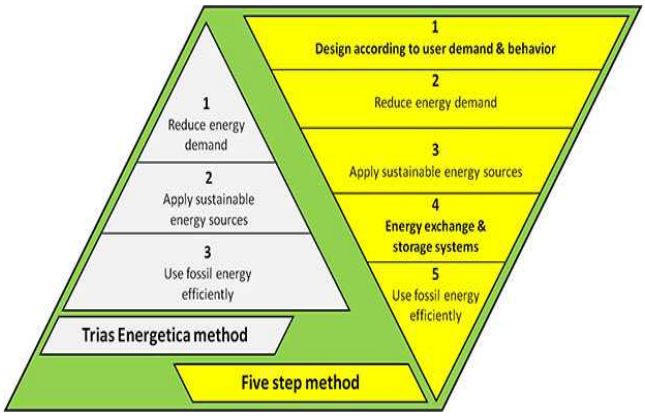

Figure 2

The Energy Used

Since the inception of the concept of NZEB, it is considered that most of the energy used in the building is for achieving thermal comfort i.e. heating/ cooling etc. Initial attempts were to design buildings that either use passive strategies for heating and cooling or are self-sufficient during typical climatic conditions of that place. Based on this idea a different definition for NZEB was proposed stating that ZEB is designed to be self- sufficient in space heating and hot water supply during typical climatic conditions. There are other researchers who also propose that the definition of a ZEB should incorporate not only the energy used during the operational period of a building but also the embodied energy associated with building construction and operating systems.

Basically the type of energy used can be categorized as follows-

- Building related- operational costs, systems and services.
- User related- lighting etc.
- Construction related- embodied energy.

In most of the calculation methodologies featured in the EPBD, the total use of energy including the building and user related energy is taken into account and the embodied energy is not commonly taken into consideration.

The Type of Balance

There are basically two types of possibilities in case of the energy balance – one for the off-grid NZEBs and one for the grid connected. It is quite clear that for the off-grid connection ZEB the energy use has to be offset by renewable energy generation preferably on-site. The issue of balance is more related to the grid connected ZEBs. There are two possibilities in this case.

- Like the definition suggests, the energy used is generated by renewable source (on or off site)
- The energy supplied to the building by the grid is balanced by the energy fed into the grid.

The most favored balance is the one between the amount of energy required and the amount of energy generated through renewable means. Among the methodologies featured in EPBD, this particular approach is used by eleven out of twelve methodologies.

Alternatives of Renewable Energy Supply

There are two possibilities of energy supply options.

- On- site supply
- Off- site supply

The definition in EPBD states that the amount of energy required by the building should be provided to a significant extent by energy from renewable sources produced either on-site i.e. within the building footprint or within the building site, or off-site. Torcellini et al. tries attempts to categorize into ranks, the preferred application for renewable source. These are

- Reducing energy consumption using active and passive techniques like day lighting, ventilation, efficient services (HVAC), evaporative cooling etc.
- Using renewable energy sources within the building footprint or site such as the PV, solar hot water, wind energy etc.
- Use of renewable energy sources available off-site like the biomass, wood pellets, biogas etc
- Invest in offsite renewable energy source like green purchasing options etc.

Connection with the Energy Infrastructure

In the concept of NZEB, the building is not just an energy consumer, but also energy generator (energy can be restricted to production from renewable source of energy). In both cases of grid connected and off-grid NZEB, the basic difference is the connection to the energy infrastructure. In the case of grid connected ZEBs, the concept is very clear- it states that the NZEBs are the buildings that deliver as much energy to the supply grid as they use from the grid. In case of off-grid, the building is a stand- alone self- sufficient system. These are defined as autonomous buildings that have the capacity to store energy for night time or winters. The issues associated with storing the energy like creating large storage capacity or battery rooms, loss of energy during transfer, providing a backup etc. in case of off-grid NZEBs results in absence of global implication.

Building Requirements

There are certain requirements that the building needs to meet in order to qualify for construction. These are mostly related to energy and comfort. They are energy efficiency requirements, indoor climate requirements, building grid interaction requirements to be more specific.

In case of energy efficiency requirements, Laustsen explains that in principle a zero energy building can be an existing traditional building provided with a very large solar collector and a solar PV system, if these systems collectively produce more amount of energy annually than the actual requirement of the building, the goal of zero energy is met. Also as per the definition a ZEB is a building that greatly reduces the energy needs either through passive measures and the

remaining energy needs can be satisfied through using renewable resources.

The issue of indoor climate requirement is yet to be developed and discussed in the ZEB definitions. There are very few analyzed definitions that touch upon this aspect mainly by considering day-lighting, natural ventilation, and choice of materials. In certain cases other aspects like sufficient artificial light control, indoor air quality, thermal comfort, acoustics etc. are taken into consideration.

The third criterion, regarding building grid interaction requirements, is highly neglected in the definitions of NZEBs indicates that due to difference in the quality between consumed and supplied energy, the utility grid gets enormously affected. Hence it is

Recommended that energy supplied back to the grid should have the same usability as the energy taken from the grid.

PROCEDURE FOR ACHIEVING "NET-ZERO" STATUS

Retrofitting and ground-up initiatives. Are two basic methods of creating a net-zero building: Minimizing the building's overall energy consumption is the first step? Next step is the planning process; retrofitting projects should make most changes ahead of time.

Basic measures have to be taken to reduce the amount of energy needed to run the facility before modifying the building or adding on-site renewable energy systems to existing infrastructure that is as simple as using LED lights, such as direct Led flourescent replacement tubes, or exchanging an old refrigerator for a Steca PF166. Heating, cooling, and ventilation accounts for about 30% of overall energy consumption in commercial buildings, it is advisable to consider upgrading aged HVAC systems to newer Energy Star HVAC systems. Furthermore, setting the temperature to 69 degrees in the winter and 78 degrees in the summer can make a noticeable difference.

Energy efficient design techniques will be implemented to reduce the amount of energy used in heating, cooling, ventilation, lighting of new infrastructure.

- In Passive solar design maximum use of the sun's light with features like south facing windows and strategic shading to illuminate rooms during the day without too much heat, reducing the need for artificial light and HVAC systems. Many buildings were not originally designed to make use of passive solar technology, which can pose a series of obstacles while retrofitting a building. Constructing net-zero buildings from scratch is advantageous in this area.
- Whether retrofitting or constructing buildings with net-zero in minds, it is imperative that building contractors, property owners, and CEOs collaborate in the design process to maximize the success of the project. The goal is to achieve net-zero status with the most cost effective strategy, which will require a financial forecasting, analyzing and planning for anticipated energy consumption, and attention to every detail of the project.

In achieving net-zero status in addition to boosting a building's energy efficiency and spending time devising a plan, the conduct of a building's occupants is an important factor. The occupants of a building must change their behavior to conserve energy by becoming accustomed to turning off lights and office appliances. "Sleep settings" must be used by everyone using a computer. Some sort of incentive must be given for implementing energy conservation.

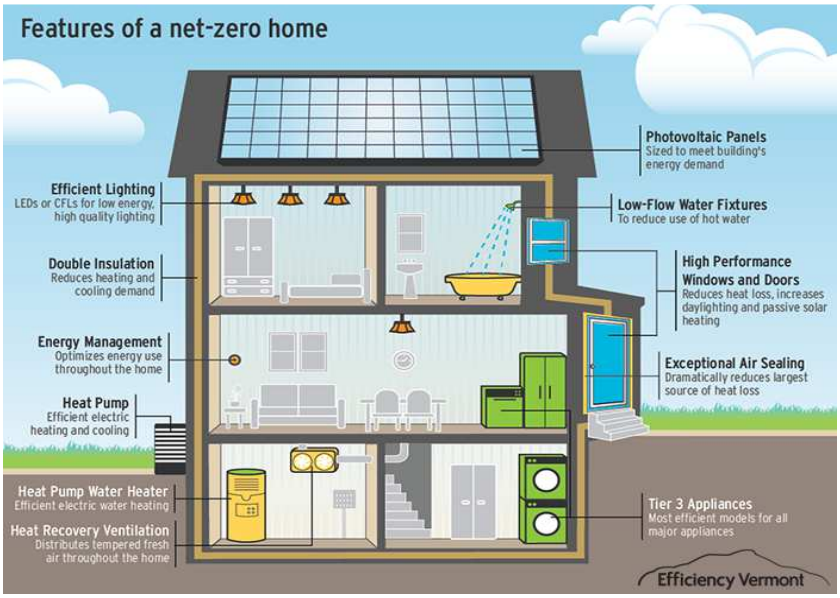

Figure 3

CONCLUSIONS

In this paper net zero energy buildings are defined technically. Following are the clarifications needed to be considered:

- Energy flows that has to be included
- Primary energy factors must be used for primary energy indicator
- Definition of system boundary with inclusion of active solar and wind
- The technical meaning of EPBD recast so that it may define existing district heating or cooling network or any other technical system serving a group of buildings

Definition of EPBD is energy performance of the appliances (households and outlets) was included, i.e. all energy used in buildings would be accounted. On closer examination of definitions of NZEB and various calculation methodologies proposed, it is very clear that the concept of NZEB is complex and there are a variety of aspects as well as issues that need clarification before any further implementation of the ZEB. The study shows that the metrics, the period and the energy types included in the energy balance with the renewable energy supply as well as other aspects like the connection to the energy infrastructure, the indoor climate and building grid interaction, all discussed in the paper are the most important concerns. Even though it is anticipated that the NZEB will help to offset 30 to 80% of energy consumption, it will not be possible without a robust methodology and universally acceptable definition of NZEB. This paper presented a literature review of existing NZEB definitions and featured energy balance calculation methodologies for NZEB to understand various important aspects associated with NZEB definitions and calculation methodologies.

DEFINITIONS AND ABBREVIATIONS

- **Exergy-** is the energy that is available to be used. After the system and surroundings reach equilibrium, the energy is zero.

- **EPBD**- Energy Performance of Building Directive
- **NZEB**- Net Zero Energy Building
- **UNEP**-United Nations Environment Program

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