Zero Energy Building: Systematic Literature Review

Vedamerta Made Oka Resia, Mohammad Reza Bahrami

1. Introduction

A Zero Energy Building (ZEB) is a building with nearly zero electricity consumption, which implies it produces renewable energy to fulfill the building's energy needs. Zero Energy Buildings have many meanings and names, including Net Zero Energy Buildings and Nearly Zero Energy Buildings. According to [1], ZEB is an ambiguous word that might be used to represent a building with features such as equivalent energy production to use, considerably decreased energy needs, and energy expenses equaling zero or net zero greenhouse gas (GHG) emissions.

Despite the uncertainty of the ZEB definition, the idea of ZEB has gained international attention in recent years and is now seen as a potential objective for architectural design. For example, most nations are attempting to implement the ZEB idea in order to save nonrenewable resources such as fossil fuels, which are needed to create energy. Furthermore, because ZEBs employ renewable sources, they offer benefits in the field of protecting the environment due to the reduction of CO2 emissions and energy usage in the building sector. ZEB is encouraged because it is critical to save the world from the greenhouse effects of gases such as carbon dioxide emitted into the atmosphere by the combustion of fossil fuels. However,to achieve the most optimal implementation of ZEB, it is important to understand all parameters which affect ZEB.

The primary goal of this report is to provide an overview of existing ZEB definitions, concepts, optimization, and implementation. The review revealed that ZEB is a complicated topic that is defined using a variety of terminology, implementations, methodologies, and expressions. Different approaches to the ZEB implementation, aspect, and definitions are assessed using existing literature.

2. Articles categorization (we will use it for SLR)

Categories	Articles
Definitions, Building energy codes, ZEB achieving, Designs, Policies, Clusters	**[2],[12]**
Thermal comfort	**[5]**
Costs, Economic optimization	**[9],[12]**
Materials	**[5]**
Performance Analysis, Clusters optimizations, control	**[3], [4], [6],[11]**
Countries, Different climates	[1] → Australia, [5] → Western China, [7] → Europe [8] →**Sweden and Norway**, [10] → Mediteranian Climate, [11] → Ireland
Renewable energy (production), Load matching analysis, Grid analysis	**[2], [3], [9], [10]**
Comparison and type of comparison	**[5] Various material layer orders and PCM layer thicknesses**
Implementation	[10] → Greenhouses

3. Result

The ZEB concept has gained significant social attention in recent years and was regarded as the future target for building design. However, before the ZEB concept can be implemented fully in global construction standards, it needs a consistent and clear interpretation as well as widely accepted energy evaluation metrics. According to [2] before developing a new ZEB definition, the following issues should be prioritized: (1) the measurement of the equilibrium, (2) the adjusting time frame, (3) the kind of energy utilize remembered for the equilibrium, (4) the sort of energy equilibrium, and (5) the acknowledged sustainable power supply alternatives. (6) the association with the energy framework and (7) the prerequisites for the energy proficiency, the indoor environment, and on account of lattice associated with ZEB for the structure network communication. Moreover, [2] concentrates on an analysis of the variety of alternative ZEB concepts as well as diverse methods to potential ZEB calculation methodologies. The results present potential solutions to the issues raised above in order to support the implementation of a reliable ZEB interpretation and a solid energy standard measure. However, there is a limitation in [2] which is not calculating the impact of installing ZEB's material in the buildings.

Furthermore, article [3] proposed a unified approach to mitigate energy problems in ZEB. ZEB integrates and models a multi-carrier power system that includes hydro-wind-solar-hydrogen-methane-carbon dioxide thermal energies. Hydro-wind-solar, combined heat and power (CHP), and pumped hydro storage(PHS) power the electrical sector. The thermal part is provided by CHP, electric heating and thermal boiler. The Methanation process and the hydrogen storage system serve as energy carriers that connect thermal sectors and the electrical. In the methanation process, The ZEB's capture the carbon dioxide (CO2). The goal is to reduce the amount of CO2 released into the atmosphere while successfully supplying most electrical-thermal load requirements in the face of events and disruptions. The approach enhances energy resilience while reducing pollution to the environment. The outcomes illustrate that the proposed design reduces CO2 emissions by approximately 33451 kg annually. The concept is a resilient energy system that can withstand component failures. The model applies a 26 percent increase in load demand and a 110 percent increase in thermal loads with ease. However, there is a limitation in [3] which is not calculating the cost control of installing ZEB's material in the buildings.

The concern in ZEB optimization is to develop the best combination of design strategies to address a building's energy performance issues. Moreover, [4] describes a methodology for multi-criteria maximization of ZEBs using simulation. Its important parts are four steps: building simulation, optimization process, various-criteria decision making, and testing the robustness of the solution. The method is used to evaluate the cost-effectiveness of enhancing the efficiency of NZEBs in a variety of studies in France and

Lebanon. Among the parameters explored are the thickness of outer walls insulation, cooling and heating set points, window to wall ratio, and window glazing type. In addition, the analyzed RE systems involve solar domestic hot water (SDHW) and photovoltaic (PV) arrays. The proposed method is a beneficial tool for improving ZEB concept and facilitating strategic decisions during the early stages of architectural design. The NSGA-II is selected to reduce life cycle cost (LCC), electrical and thermal while achieving net zero energy stability and thus achieving the Pareto-front. A method of ranking decisions The Elimination and Choice Expressing the Reality (ELECTRE III) algorithm is applied to the Pareto-front in order to find the best solution. The limitation of [4] is the model is not globally applicable due to it not analyzing the climate aspect.

In fact, one of the most important aspects to developing zero energy buildings is to adjust the climate around the ZEBs. For instance, during the cold period in Western China, weather conditions are determined by a wide daily thermal area and high radiation from the sun, and improving building thermal storage productivity is an efficient passive cooling development method for ZEBs. The purpose of [5] is to look into the thermal storage efficiency of building covers under normal conditions. To enhance the thermal storage efficiency of an experimental chipboard, a phase change material is embedded. A dual periodic thermal effect is used in the outdoor and indoor environments during the test to visualize the heat transfer in buildings. Various material layer orders and PCM layer thicknesses are evaluated by comparing to investigate the main factors influencing thermal storage efficiency. To measure the two factors, the thermal inertia indicator and coefficient of thermal stress are used as important parameters. According to the findings, increasing the coefficient of thermal stress for the wallboard by maximizing the order of the material layer can minimize fluctuations in the temperature in the room by 31%. However, simply increasing the thickness of the thermal storage component somehow doesn't enhance the absorption and lag time impact of the wallboards drastically. The heat concentration coefficient is suggested as an important parameter in the structure of ZEBs. The thermal storage wall model and important factors analyzed in this paper could serve as a framework for the implementation of ZEBs in Western China. However the author states that there are some limitations in [5] namely, 1. Just the warm stockpiling execution of the misty divider is researched. The impact of warmth conduction on the indoor warm climate is examined, yet the warmth radiation and the convection of indoor and outside air are not thought of; 2. The space of the test chamber is more modest than the genuine structure, and the indoor air temperature change is all the more fundamentally influenced by the inner warmth source; 3. The exploratory wallboard is more slender than the genuine structure divider, and the temperature/heat motion esteems got in the examination can portray the warm stockpiling qualities, yet it is not the same as the worth under genuine conditions.

Furthermore, The other aspect that should be included to evaluate ZEB is the performance gap. In [6] the results show that the difference in performance is either not especially substantial or may be overcome by technological advancements or changes in human behavior. The method that is used in [6] consists of four steps: 1. Choosing the buildings for study case, 2. Analyzing the structures and its system designs, and assessing power and energy demands using dynamic thermal simulation models are all part of the second phase. 3. The third stage is to gather data when the buildings are operating in actual environments. 4. The fourth phase is an evaluation of the building outcomes and the extraction of helpful observations and conclusions. However the author does not consider the climate aspect which is a limitation of this study.

On the other hand, the European plan focuses on reducing energy usage in buildings to guarantee that future climate and energy objectives are met. The concept of ZEBs, which provide potential to enhance energy efficiency in Europe, is the subject of [7]. Because this word appears to be open to several interpretations, the study investigates the ZEB literature to offer an overview of conceptions. The study highlights discrepancies and key concerns. The study also examines the status of ZEB implementation throughout Europe, as well as the key disputes that have developed in relation to ZEBs. Between these themes are the distinctions between primary energy and energy, as well as the distinctions between energy carriers and energy sources. Particular care is taken in determining fundamental energy parameters for energy carriers derived via renewable energy on-site, locally, or far away. Following the concept of “plus” structures, a supplementary electricity index is formulated to solve concerns about the “negative” main energy index that may be produced using certain of the present net ZEB definitions. A proposal is also made to define the concept of plus energy buildings, ZEB, and near ZEB. The study reveals that, despite greater attention to ZEBs in recent years, the subject is still being debated and is not being applied universally. However the author states that there is a limitation in [6] which is The assignment of ZEB ought to be utilized uniquely for structures that have shown through real yearly estimates that the conveyed energy is not exactly or equivalent to the on location inexhaustible traded energy

Moreover in [8], the study investigated how widespread adoption of ZEBs affects cost-effective assets in the Scandinavian energy source toward 2050. A probabilistic TIMES prototype with an explicit consideration of the short-term instability related to energy production and heat requirement in buildings performs the analyses. A ZEB, according to the authors, is an extremely effective construction with on-site PV panels. Author recognizes no use of storing energy within the ZEBs to analyze the portability demand of the surrounding power system. According to the findings, ZEBs decrease savings in nonflexible wind power and hydropower while increasing the use of immediate electric boilers and electric heating. ZEBs enhance Scandinavian energy production by 16 TWh and electricity power transfer by 19 TWh in 2050, with integrating construction PV output of 53 TWh. Even though increased outcome lowers energy costs, the lower thermal availability in ZEBs results in a 4 TWh reduction in electricity consumption in 2050. Finally, the results show that the Scandinavian electricity generation can integrate a large number of ZEBs with periodic PV panels due to adjustable hydropower in Sweden and Norway. However, there is a limitation in [7], the author not evaluating the worst-case scenario that might happen to the power system, which then affects the result of this study.

Apart from the ZEB concept there is an important aspect that is missing to build a comfortable residence which is Heating, ventilation and air conditioning systems (HVAC). HVAC accounts for the majority of electricity use in apartment complexes and is critical to the wider adoption of ZEB. In [9], the aim of study is to evaluate the economic performance, energy, and convenience of commercially available HVAC systems for a residential ZEB. In the mixed-humid climatic zone, an experimentally verified prototype was used to analyze dehumidification, ventilation, and heat pump alternatives for the ZEB. When compared to mechanical ventilation without restoration, heat recovery ventilators (HRV) and energy recovery ventilators (ERV) saved HVAC energy by 13.5 percent and 17.4 percent, respectively and decreased the building energy by 7.5 percent and 9.7 percent. In terms of thermal comfort, there was no large disparity between the ventilation choices. Dehumidification alternatives were evaluated to an air-source heat pump (ASHP) with a dedicated dehumidifier; the ASHP with dedicated dehumidification decreased HVAC energy by 7.3% and building energy by 3.9%. In contrast, The ASHP without dedicated dehumidification offers the least amount of comfort owing to high humidity levels, but it was the least expensive. Furthermore, ground-source heat pump (GSHP) options were evaluated to the ASHP; the GSHP with 2 and 3 boreholes lowered HVAC energy by 26.0 and 29.2 percent, respectively, and building energy by 13.1 and 14.7 percent. Using setup cost information and two energy pricing models, the economics of each HVAC setup were examined. The ERV with the GSHPs and specialized dehumidification saved the most energy and gave the most comfort, but they were the most costly. The payback times for the ERV and the ASHP with specialized dehumidification were fair. However, there is a limitation in [8] which is not calculating the cost control of installing HVAC in the buildings.

The implementation of ZEB concept is not strict at residence blocks. The ZEB concept also can be applied to another type of building such as Greenhouse. Greenhouses are globally used throughout the world, particularly in Mediterranean zone, to have an appropriate atmosphere for the planting of various agricultural crops. These crops require a lot of energy to generate, process, and allocate. According to [10], different methods to implement the ZEB concept are used In greenhouse, such as steam or warm water radiation mechanisms and warm air heating systems. Moreover, An enhanced geothermal system is being explored for a greenhouse since it can offer both heating and cooling power. The objective is to assess a renewable energy choice for a greenhouse's total energy requirement. Grid-integrated solar photovoltaic modules are chosen to supplement a deep geothermal heating system and produce electricity for lighting. In this approach, a zero-energy greenhouse idea for three distinct agricultural commodities is envisaged. The greenhouse's monthly and yearly heating, lighting, and cooling energy loads for various agricultural products were calculated. The average monthly power output of 66 photovoltaic, which covers 50% of the asymmetric roof's southern face, was estimated. The annual photovoltaic production was calculated to be 21510.4 kWh. During the summer operating months, solar power output can satisfy 33.2–67% of greenhouse demand. Nonetheless, the coverage ratio, determined by dividing the solar panels' power output by the greenhouse's electricity requirement for each crop, was quite high throughout the winter operation seasons. Annually coverage ratio figures for tomato were 95.7 percent, 86.8 percent for cucumber, and 104.5 percent for lettuce. These high coverage ratio figures support the practically zero energy notion for the greenhouse under consideration. The examined system's economic and environmental evaluations were also completed. The crop cultivations' basic payback time was calculated to be somewhere between 7.0 and 7.4 years. Based on natural gas and coal-based power generation, the system's energy payback time was determined to be 4.9 years, and the greenhouse gas payback time values of 5.7 years and 2.6 years were estimated, respectively. However, there is a limitation in [10] which does not evaluate the environmental impact that exists due to installing ZEB's material in the greenhouses.

There are various ways for designing and creating ZEB. However, the prototype design for a structure is influenced by a variety of elements such as position, weather, budget, resource availability, and so on. The goal is to discover the optimal mix of design techniques to address a building's energy performance issues. [11] shows the results of an amount of case study buildings in Ireland that concentrate on the life cycle cost and environmental evaluation of ZEBs that use numerous heat resources. With the de-carbonization and expanded productivity of the power network, the low an Earth-wide temperature boost potential emanations of biomass energizes, and the exhaustion of petroleum derivatives, future structures ought to be (I) planned and built to be super-protected with high air-snugness execution, least warming necessities and (ii) work with warming frameworks that modest affect the regular environment, like a biomass evaporator or heat siphon. The limitation of [11] is the proposed models cannot be applied universally due to lack of parameters that are used in it.

Saving energy via building energy efficiency has gained prominence all around the world. The 4 major parameters for energy conservation in a building according to [12], namely, first zero energy passive construction techniques prior to actual design, secondly, the use of reduced energy construction materials during installation, Third, utilize electricity equipment to reduce operating energy requirements, and last, integrate renewable energy technology for a variety of applications. These elements, as well as their environmental and economics implications, have been concisely explored in this study. The first component is connected to the preceding design proposed building of a solar passive construction methods that have been used all across the country for daylighting the structure. The second step is to use low energy intensity construction materials in building construction. The third component is concerned with energy consumption saving through the use of energy-efficient equipment. Finally, the building must contain linked renewable systems. In [12], there is a limitation with the major parameters that are used, it does not consider climate factors in creating ZEB models.

Article [13], [14], and [15] are excluded in this report due to the main focus of those article is not about ZEB concept

4. Discussions

In this section, we will write about the limitations/pros, and cons of each article that we mentioned in the previous section (sec. 4) and how you will suggest/propose to improve the article (solve issues).
Some articles may have the same/similar solutions, therefore we categorize them and will write a paragraph about them.

5. Search questions

The research questions that may your report answer are:

1) Why are ZEBs concepts important?
2) What is the definition of ZEB?
3) How to implement ZEB concepts?
4) What parameter can affect ZEB?
5) What is the benefit of ZEBs?

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