

The potential of net zero energy buildings (NZEBS) concept at design stage for healthcare buildings towards sustainable development

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Abstract. The focus on net-zero energy buildings (NZEBS) has been widely analysed and discussed particularly when European Union Parliament are progressively moving towards regulation that promotes the improvement of energy efficiency (EE). Additionally, it also to reduce energy consumption through the recast of the EU Directive on Energy Performance of Buildings (EPBD) in which all new buildings to be “nearly Zero-Energy” Buildings by 2020. Broadly, there is a growing trend to explore the feasibility of net zero energy in healthcare sector as the level energy consumption for healthcare sector is found significantly high. Besides that, healthcare buildings energy consumption also exceeds of many other non-domestic building types, and this shortcoming is still undetermined yet especially for developing countries. This paper aims to review the potential of NZEBS in healthcare buildings by considering its concept in design features. Data are gathered through a comprehensive energy management literature review from previous studies. The review is vital to encourage construction players to increase their awareness, practices, and implementation of NZEBS in healthcare buildings. It suggests that NZEBS concept has a potential to be adapted in healthcare buildings through emphasizing of passive approach as well as the utilization of energy efficiency systems and renewable energy systems in buildings. This paper will provide a basis knowledge for construction key players mainly architects to promote NZEBS concept at design stage for healthcare buildings development.

1. Introduction

Over the years, the concern of energy efficiency along with the attention on net-zero energy buildings (NZEBS) has received incrementing attention by most countries. NZEBS concept is developed to represents a zero or low energy building that using renewable energy systems installed to meet the buildings energy consumption demands [1]. In the context of Malaysia’s construction industry, the government has recognised the important concern of energy consumption and negative impacts of the inefficient use of energy in developing the country. It can be clearly seen through Construction Industry Transformation Programme (CITP) 2016-2020 which one of strategic thrust that seeks to transform the industry is environmental sustainability [2]. Generally, between 1978 and 2014, the residential and commercial sector’s final energy demand in Malaysia had increased rapidly to reach 7458 ktoe [3]. As a result of uncontrollable energy consumption of resources and energy, the sector has been greatly responsible for problems related to environmental sustainability. However, despite



today's buildings energy consumption demand increasing significantly, NZEBs concept practices enable to develop a network of clean domestic energy assets.

Healthcare buildings is a complex building since these buildings involve several of service area which requires different working environment [4]. For instance, in the current Malaysia healthcare built environment, with healthcare building as the main energy users, reducing CO₂ emission and improving energy efficiency are becoming more important. Based on Kamaludin *et al.* [5], healthcare building built environment in Malaysia associated with great energy consumption and CO₂ emissions. It is important to realise that the accumulation of carbon dioxide CO₂ emission may result in global warming [6].

Besides that, according to the study that has been conducted by Shaza & Rozana [7] Amanjaya Specialist Center Green Hospital and Columbia Hospital, Petaling Jaya are the only two numbers of private healthcare buildings have been evaluated by using GBI NRNC rating system and achieved as 'certified' category. Contrastingly, none public healthcare buildings in Malaysia certify under the GBI system. With the attention to this issue, it clearly showed that the implementation of healthcare sustainability as well as energy efficiency awareness is still at a low level. Therefore, NZEBs should become a core concept that needs to follow by all construction players as well as government agencies.

2. Net Zero Energy Buildings (NZEBs) concept

This section presents a fundamental aspects of the net-zero energy buildings (NZEBs) concept that used currently. An overview of NZEBs as highlighted by Patiño *et al.* [8] are buildings that achieve the benchmark of efficiency by following or overcoming a list of technical fundamentals. Furthermore, NZEBs concept is developed to represents a zero or low energy building that using renewable energy systems installed to meet the buildings energy consumption demands [9]. The concept was analysed in several perspectives. The detail discussion of NZEBs definitions is explained in the following subsection 2.1.

2.1. What is NZEBs?

The earliest definition and classification of net-zero energy buildings (NZEBs) can be found in the study by Paul *et al.*, [9], that the authors addressed four main primary definitions of NZEBs. The four main definitions for various types of NZEBs according to Paul *et al.* [9] are net zero site energy, net zero source energy, net zero energy costs, and net zero emissions as illustrated in Figure 1. According to the four definitions, it pointed out that the NZEBs is a grid connected building where the annual energy generation from a renewable source is equally with energy consumption during the term of one year. Similarly, Sartori *et al.*, [10] emphasized that NZEBs is conceptually a building with a lower of energy demand and are balanced by the on-site generation of electricity, or other energy carriers, from renewable sources. Moreover, the authors also mentioned that the term NZEBs refer to buildings that are connected to the energy infrastructure. Furthermore, another study by Kurnitzki *et al.* [11] and Karsten *et al.* [12] highlighted that NZEBs are typically a grid-connected building with a very high energy performance.

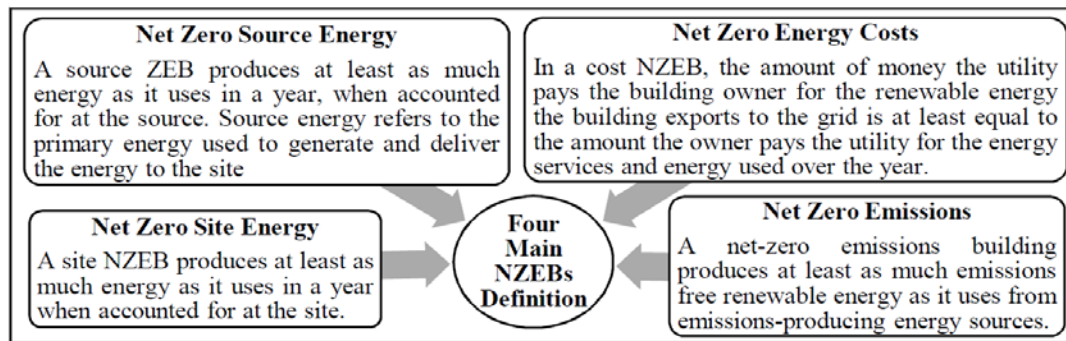


Figure 1. Four main definitions of NZEBs [9].

However in 2009, The Massachusetts Zero Net Energy Buildings Taskforce which comprised of more than 70 leaders has been worked together to establish key solutions that will guide to the worldwide adoption of NZEBs and deep energy reduction retrofits throughout the Commonwealth by 2030. The taskforce defined NZEBs as a building that is capable to generate energy onsite with a quantity that is equal to or greater than the total quantity of energy consumed onsite within a period of a year, and the building uses clean renewable resources [13].

2.2. What are NZEBs criteria?

The continuous improvement on the NZEBs definition can be seen through the study of Sartori *et al.* [10] which introduces a harmonised framework for describing the important elements of NZEBs in a series of criteria. Based on their study, the authors have listed several criteria that should be questioned and addressed in order to strengthen the overall NZEB “goodness of design” as well as to give a sound NZEB definitions in a formal, systematic and comprehensive way [10]. The summary of the scope of questioned criteria among the task activities is illustrated as in Figure 2.

First Criteria	Boundary Condition
•System boundary (Is the boundary on a single building or on a group of buildings?)	
•Functionality and effectiveness (What type of building is it?)	
•Climate and Comfort (What is the reference climate?)	
Second Criteria	Crediting System
•Credit metrics (What metrics is used?)	
•Credit accounting (How are the credits accounted for?)	
Third Criteria	Net Zero Balance
•Item of balance (What loads are included in the balance?)	
•Balancing period (What is the basis for calculating the balance?)	
•Energy efficiency (Are there mandatory minimum requirements on energy efficiency?)	
•Energy supply (Is there an explicit hierarchy of supply options?)	
Fourth Criteria	Temporal Energy Match
•As grid connected buildings are investigated, it is useful to define some indicators which can evaluate the impact on the energy carrier exchange between the building and the energy infrastructures.	
Fifth Criteria	Monitoring Procedure
•Is the definition based only on design data and simulations or a monitoring procedure is mandatory to check the effective balance?	

Figure 2. NZEBs definition criteria [10].

Additionally in 2012, a consistent framework for setting NZEB definitions has been developed through the study of Sartori *et al.*, [14] in which evaluation of the criteria in the definition framework and selection of the related options becomes a methodology to set NZEB definitions in a systematic way. According to the study, the authors stated that there is the difference between the terms of net-zero energy buildings (NZEBs) and zero energy buildings (ZEBs) as the terms of ZEBs is broader and it could include autonomous buildings. The wording 'Net' in NZEBs indicates that the energy obtained from and provided back to the energy grids nominally within a period of a year is a balance [14]. Moreover, the study showed that the core concept of NZEBs is where there is a balance between weighted supply and weighted demand. In other words, the sum of all generated energy is equal to the sum of all delivered energy.

Therefore, since 2006 to 2012, much improvement on NZEBs definition had been made in order to give a sound and comprehensive definition of this concept. Hence, it is understood that NZEBs represent buildings that connected to the electricity grid and the total energy usage is equal to the total 'onsite' generation of energy from a renewable source over the course of a year.

3. Adapting NZEBs design features for healthcare buildings

There are numerous different methods to reach net zero energy balance within a year. Based on Matt *et al.*, [15] there is a growing interest in NZEBs as many NZEBs demonstration projects showed that the goal of this concept is achievable. However, the need to identify NZEBs approaches is crucial in order enable broad replication of NZEBs. Furthermore, according to Aelenei *et al.*, [16] in the study on close inspection of the relevant design strategies and relative performance indicators of the eight case studies, the authors stated that there is no standard approach for designing NZEBs. Similarly, Gandhi *et al.*, [17] highlighted that it is important for architects or engineers to have specific design guidelines and strategies in order to popularize NZEBs. Even though there are still no specific design strategies in achieving NZEBs design, but based on Yuehong *et al.* [18] there are several common design elements and some consensus in designing NZEBs.

Generally, according to Aelenei *et al.* [19] and Yuehong *et al.* [18], there are three main steps of design approaches that can be applied in designing NZEBs which are the first design approach is passive approach that focused on reducing energy demand. The second design approach is the use energy efficiency system, and the third design approach is renewable energy system which is needed to generate renewable energy as well as to offset in large measure the energy demand. The combination of this three design approach able to succeed in reaching the desired energy performance as well as NZEBs target. Therefore, this section intends to analyse the current design practices of NZEBs and the detail explanation of the first design approach will be explained in subsection 3.1, subsection 3.2 will explain on the second design approach and the third design approach will be explained in subsection 3.3.

3.1. First design approach: passive approach

Passive approaches are one of the key element when designing NZEBs as this approach will affect directly to the energy needs for the buildings mechanical and electrical systems, and also indirectly affect the renewable energy generation [16]. Similarly, Alessandra *et al.*, [20] also highlighted that the passive approach plays a significant part in the NZEBs design. Besides that, the improvement of energy consumption of a building can be achieved through passive design strategies as buildings are constructed that react to the environment, hence it is possible for a building to achieve high environmental quality [21].

Furthermore, Gandhi *et al.*, [17] stated that architects have an important role in controlling aspects of passive design when designing NZEBs. One of the most significant aspects of passive design strategies is maximizing the amount of natural daylight into a building and reduce the amount of energy requires for artificial lighting in a building [22]. Besides that, it is important to control passive design strategies in a building as this approach will influence the energy performance of a building such as natural lighting, heat gain, shading, and envelope conduction.[17,23]. In addition, Aleinei *et*

al. [16] stated that the passive design strategies in buildings should be appropriately orientating building towards solar heating maximization when buildings are dealing with heating challenges. Moreover, according to Thalfeldt *et al.* [24] when designing NZEBs, façades has a strong impact on heating, cooling and artificial light in the building needs as well as on daylight. Thus, it is important to realise that the passive heating solutions are essential to be studied along with passive cooling solutions in order to prevent overheating in a building [16].

This indicates that it is important to consider passive approach such as orientation, shading devices, ventilation and thermal insulation while designing NZEBs as it will enable the reductions of energy needs in buildings and this approach able to provide significant benefits for healthcare buildings.

3.2. Second design approach: energy efficiency system

Energy efficiency has a significant part to act as a parameter that indicates the reduction level of energy consumption in carrying out a related task [25]. Besides that, it is important to realise that the pathway towards NZEBs is reducing energy demand by means of energy efficiency measures [10]. Therefore, energy efficiency measure plays a significant role towards NZEBs as it is one of the key actions in achieving NZEBs target. Moreover, the government of Poland also has supported the energy efficiency measure in order to successfully implementing NZEBs [26]. The main purpose to enhance energy efficiency for the reason that it will able to protect scarce energy resources as well as to minimise the costs of energy by means of preventing wastefulness, and possibly to minimise carbon dioxide (CO₂) emissions which will effect to climate change [27].

Generally, energy efficiency can be improved by several design strategies including airtightness to avoid infiltration and mechanical ventilation systems with heat recovery to provide air conditioning and indoor air quality (IAQ) [28]. However, the selection of high-efficiency technologies is also crucial in the improvement of energy efficiency in a building. For instance, the use of low power lighting, energy efficient electrical equipment such as washing machines and dishwashers with a warm water connection are strategies in planning an equated energy balance [29].

Similarly, based on Maassen [30], healthcare building's energy demand can significantly reduced by considering energy efficiency as a factor in buying medical equipment, besides the proper use of electricity. Furthermore, many researchers have demonstrated that by implementing different energy efficiency measures in a building, the variation of energy savings can be achieved. According to Erica *et al.*, [31] that carried out an investigation of the effectiveness of energy efficiency measures for different occupancy patterns. They concluded that similar savings to passive approach and conversion devices can be achieved through the combinations of less expensive and less invasive energy efficiency measures. As a result, these energy efficiency measures options should be greatly promoted.

In addition, based on Rahmi [32] in the investigation of energy consumption reduction by utilizing high-efficiency office equipment and HVAC system by using DesignBuilder as simulation tool in this research. The simulation findings showed that there are several factors generally will give significant impacts to the reduction of cooling energy demand in buildings. The factors involved are the application of high-efficiency HVAC system, the use of high performance glazing material (low SHGC value and high light transmission value) for building envelope with majority glass façade and involving task lighting which includes the lighting sensor and indoor set point temperature.

This shows that the adoption of energy efficiency measure such as energy efficient mechanical system and energy efficient electrical system in a building is vital towards NZEBs as energy reduction, as well as energy savings in healthcare buildings, can be achieved. Moreover, by improving the energy efficiency of the various incorporated building systems, it will help to reduce building's energy demand [33].

3.3. Third design approach: renewable energy system

The necessity of renewable energy systems such as solar electric PV and solar water heating is vital towards NZEBs since these systems are required to reduce and as well as to offset the thermal energy need in buildings. Moreover, designing NZEBs is not only achieved by reducing the energy

consumption of the building with passive design methods or the application of energy efficient system in buildings, but NZEBs should also be designed with the balances energy requirements between active energy production techniques and renewable technologies in order to achieve the NZEBs objective [34]. In this regard, innovative renewable energy system strategies have to be taken into consideration. Besides that, the utilization of renewable energy systems in buildings can be a critical need and solutions against global warming and environmental pollution [35].

With respect to renewable energy systems, there are a lot of benefits that can be gain from these system and several studies have demonstrated the benefits of these systems. For instance, Phuangpornpitak & Tia [36] studying the integration of renewable energy in a smart grid system and they concluded that renewable energy system is one of incomparable option to generate energy since these systems able to provide a clean energy resource. However, they suggested that some issues such as the design, sizing, and the suitability of the system in terms cost for energy generation need to be addressed in order to ensure that it can be used thoroughly and commercially.

In addition, Rishi *et al.* [37] presented a comparative analysis of four prevalent solar lighting technologies by surveying selected photovoltaic (PV) programs in India. Authors found that a better operation of solar systems can be achieved by a strong management and monitoring mechanisms of solar PV programs. It also highlighted that the key contributors for extensive use of PV in India are strong technical, institutional and financial aspects since developing a strong framework and institutional policies vital towards achieving higher success rates in PV application. Based on Erni *et al.* [38] studied the green concept of healthcare facilities in tropics stated that utilization of natural energy and by using solar cell and the creation of a simple alternative energy is vital to minimise the energy dependency on the electricity power plant and generators. Additionally, according to Shanti & Paul [39], there are four classifications of NZEBs that based on their renewable energy sources:

- NZEB A: indicates a building uses a combination of energy efficiency and renewable sources gained within the building footprint.
- NZEB B: indicates a building uses a combination of energy efficiency and renewable sources gained within the building footprint and within the site.
- NZEB C: indicates a building uses a combination of energy efficiency and renewable sources gained from off-site to generate energy on-site.
- NZEB D: indicates building purchases certified off-site renewable energy sources such as utility-scale wind.

As a summary, there are three key areas that need to focus in order to support the implementation of NZEBs concept for healthcare buildings into action which is namely, passive design strategies, the application of energy efficiency system, and renewable energy system. These design approaches are crucial towards the reduction of energy demands in healthcare buildings as well as the generation of clean energy sources for healthcare buildings. Hence, Figure 3 shows a summary of the main design approach for NZEBs in healthcare buildings.

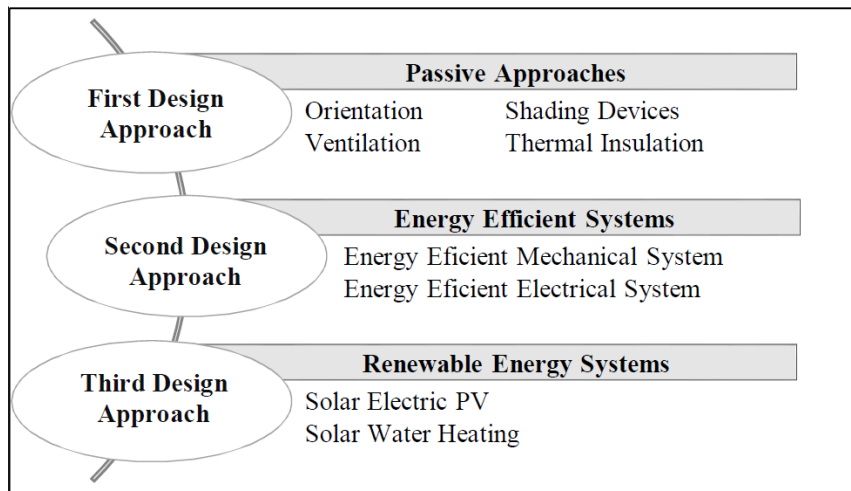


Figure 3. The main design approach for NZEBs in healthcare buildings.

4. Conclusion

Healthcare buildings is a complex building and these buildings involve several of service area which requires different working environment and the aspect of low energy and environmental control should be more focus. It is crucial to determine the principle design of healthcare buildings to achieve net zero energy buildings (NZEBs) requirement. The focus on the NZEBs in healthcare building had become significant especially in developing country. The conclusion is drawn that three principles were used to identify possibilities to reach towards NZEBs requirements for healthcare building. This principle consisted of passive approach, energy efficiency, and renewable energy systems. By considering to this context, it is expected that NZEBs concept is potential to be adopted in healthcare building for ensuring the energy improvement as well as to achieve a maximum of energy efficiency. Besides that, the adaptation of NZEBs design features into healthcare buildings will enable the healthcare sustainable development.

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