

# A Systematic Investigation on the Potential of Net Zero Energy Buildings (NZEBS) Design Approach Implementation in Healthcare Buildings

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**Abstract:** *A concept called net-zero energy buildings (NZEBS) has received incrementing attention especially since European Union Parliament are progressively moving towards regulation in which all new buildings to be “nearly Zero-Energy” Buildings by 2020. In the context of Malaysia construction industry, the government has a significant concern in energy consumption and the negative impacts of inefficient of energy usage. Although this concept provides promising benefits, however, previous studies found that the benefits of NZEB is still doubtful to the Malaysian construction industry, particularly for healthcare buildings. The NZEBs concept implementation is crucial in healthcare building as it seen as a key-part of the needed transition towards sustainable energy efficiency as well as co<sup>2</sup> emissions control in its energy dimension. This paper aims to determine benefits of NZEBs practices through preliminary investigation among architects. Several existing energy works of literature and pilot studies by using semi-structured interviews were conducted. The findings reveal that, although the term ‘NZEBS design strategies’ is not being used broadly across construction industry in Malaysia, some green practices related to the design stage of construction has been carried out. The findings are also encouraging in increasing awareness, practices and implementation of NZEBs design strategies by the practitioner in Malaysia. It is envisaged that the paper will provide a basic knowledge for future research in benefits of NZEBs, significant value and design strategies practices for healthcare buildings construction in Malaysia.*

**Keywords:** net zero, healthcare building, energy building

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## 1. Introduction

In recent years, the issue of high level of energy consumption and carbon emission are the basis for the introduction of net-zero energy buildings (NZEBS) concept, and this concept has received a great attention by most countries. By having an increasing concern in environmental issues, European Union Parliament are gradually working towards a regulation that encourage the improvement of energy consumption as well as to reduce the level of carbon emission 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 [1]. 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 [2]. Apart from that, Patiño et al., [3] stated that, NZEBs are buildings that achieve the benchmark efficiency by pursuing or outperforming a list of technical requisites. Therefore, NZEBs can represent

buildings that utilise the renewable energy technologies and able enable to develop a network of clean domestic energy assets.

The application of NZEBs concept in healthcare building is crucial because it perceived to be as a main part for the progression towards sustainability. Healthcare buildings require unique energy requirements and these kinds of buildings are complex with many people vulnerable to environmental conditions [4]. Besides that, hospitals itself, with its variety of building services, disposals of waste in large quantities, a wide range of equipment and machinery use and another addition of energy consumption, contribute to the environmental issue [5]. Significantly, global warming is a major risk facing mankind. The concentration of CO<sup>2</sup> in the atmosphere is increasing year on year, which enhances the natural greenhouse effect and warms the planet [6]. According to the Intergovernmental Panel on Climate Change (IPCC), the temperature increase during the twenty-first century will be between 1.0 and 3.7 °C, depending on the future emissions of greenhouse gases [7].

Other than that, Malaysia has awakened by the fire incident of Hospital Sultanah Aminah, Johor Bharu that claimed the lives of six people on 2016 [8]. The causes of the fire incident as reported by New Straits Times involve technical issues like sparks from capacitor ceiling lights [9]. Even though there are several other possible causes of electrical fire in a building, it is important to realise that overloading is a notable physical mechanism of electrical fire [10]. Overloading is where the electrical circuit or devices at high temperature might ignite itself and surrounding combustibles to cause a fire when the flowing current exceeds the maximum current carrying capacity [11]. Based on the issue pointed out, the application of energy efficient system often overlooked. Energy efficiency measures able to increase the level of productivity as well as to reduce the energy needed and increase the output whilst keeping energy consumption.

Therefore, the aim of this paper is to present findings on the current green design practices of healthcare buildings in Malaysia as well as the knowledge of architects towards NZEBs. Literatures find that there are various ways to design NZEBs, thus the focus is to identify which of the current green design practices for healthcare in Malaysia that are similar with NZEBs design strategies. This paper expects to give an understanding of NZEBs concept in Malaysia healthcare buildings as well as to recommend ways for construction players to design NZEBs in healthcare building in Malaysia.

## **2. Literature Review**

### **Green and Sustainability Progress in Malaysia**

Malaysian government has demonstrated their commitment towards achieving sustainable development goals by planning and setting their goals through several of national energy policies and the five-year Malaysian plan. For instance, under the recent Eleventh Malaysia Plan (2016-2020), the Malaysian government has set 4 focus area which are strengthening the enabling environment for green growth, adopting the sustainable consumption and production concept, conserving natural resources for present and future generations, and strengthening resilience against climate change and natural disasters [12]. These focus areas have proved that the Malaysian government is committed towards sustainability.

Apart from that, there are several energy policies that have been introduced by government such as National Green Technology Policy (NGTP) in 2009 where one of the objectives is to ensure sustainable development and conserve environment for future generations. Besides

that, the New Energy Policy 2010, as embedded in Ninth Malaysia Plan (2006– 2010) has been introduced by the Malaysian government which include economic efficiency, environmental, and social considerations while conserve existing resources [13] [14]. As regulator, the government’s role to improve and enforce sustainable-related regulations will bring changes at national level.

### Healthcare Project Progress in Malaysia

In general, the allocation for Ministry of Health (MoH) health expenditure which involve recurrent and development in Malaysia shows a positive trend where RM3,815 million were allocated by the federal government to MoH in 1997 to RM23,064 in 2015 [15]. Concerning to this trend, MoH health expenditure shows almost seven-fold increase over eighteen years. Even though for the last three years which are from 2013-2015, the allocation for development budget for MoH is below 10 percent, but the allocation had always been above 10 percent from 1997 to 2015, as illustrated in Figure 1.

Year	Recurrent Allocation		Development Allocation		Total Allocation	Increase in Total Allocation	
	RM Million	Per cent %	RM Million	Per cent %	RM Million	RM Million	Per cent %
1997	3,236	84.83	579	15.17	3,815	-	-
1998	3,359	82.09	733	17.91	4,092	278	7.28
1999	3,612	80.05	900	19.95	4,512	420	10.26
2000	4,214	76.56	1,290	23.44	5,504	991	21.97
2001	4,631	75.53	1,500	24.47	6,131	627	11.40
2002	5,139	74.98	1,715	25.02	6,855	724	11.80
2003	5,786	74.41	1,990	25.59	7,776	921	13.44
2004	7,026	72.67	2,643	27.33	9,669	1,893	24.34
2005	7,302	85.92	1,197	14.08	8,499	-1,170	-12.10
2006	8,206	86.35	1,297	13.65	9,503	1,004	11.81
2007	9,572	85.46	1,629	14.54	11,201	1,698	17.87
2008	10,880	83.04	2,222	16.96	13,102	1,901	16.98
2009	11,863	82.21	2,567	17.79	14,430	1,328	10.14
2010	11,765	76.65	3,584	23.35	15,349	919	6.37
2011	14,302	87.82	1,984	12.18	16,287	938	6.11
2012	15,151	89.00	1,873	11.00	17,023	737	4.52
2013	17,653	90.95	1,756	9.05	19,409	2,386	14.02
2014	20,494	93.20	1,495	6.80	21,989	2,580	13.29
2015	21,714	94.15	1,350	5.85	23,064	1,075	4.89

Figure 1: Ministry of Health (MOH) Recurrent and Development Allocation, 1997-2015. Source: (Malaysia Ministry of Health, 2015) [15]

As a matter of facts, the initial allocation of RM 1.662 billion were allocated by the federal government to MoH for the development budget has been approved, which includes constructing new hospitals, upgrading existing hospitals, facilities and others [16]. As compared to 2010, there is an increase of 2 new hospitals in 2014 where there are as much as 133 government hospitals and 9 special medical institutions [16]. MoH has spent 92.90% of the adjusted development budget allocation, or equivalent to RM 1.389 billion which comprised of 71 new MoH programs. Based on 71 new MoH programs, it is involved in 67 physical projects and 4 non-physical projects [16]. Moreover, for the physical projects, Public Works Department (JKR) will handle 53 projects while JKR Sabah and JKR Sarawak will

handle 4 projects and 3 projects respectively. The remaining 4 projects will be handled by the Engineering Services Division (ESD) of MoH [16].

Based on the statistics, it is understood that the healthcare buildings development in Malaysia is keep moving over times. Therefore, the healthcare buildings sustainability is significant to be consider in the long term. Some of the challenges need to be addressed to ensure that the goals and targets on sustainability that have been planned by the government can be achieved. Besides that, the healthcare industry transformation towards a more sustainable and effective health system in ensuring widespread access to healthcare are possible to be accomplished.

### 2.3 NZEBS notion

NZEBs concept as according to the study of Sartori et al., [17], is a concept where there is a balance between weighted supply and weighted demand. To simplify, the sum of all generated energy and all delivered energy is equal. As showed in Figure 2, the graph displayed that the energy efficiency is also one of an important factor to be considered in NZEBs. Concerning to the pathway to a NZEB is given by the balance of energy efficiency and energy supply, hence the criteria on energy efficiency and energy supply are important towards NZEBs definition [17]. In the same way, Buildings Performance Institute Europe (BPIE) in its reports entitled “Implementing Nearly Zero-Energy Buildings (NZEB) In Poland - Towards A Definition and Roadmap”, BPIE specified that the government of Poland is require supporting the energy efficiency measure to successfully implementing NZEBs [18]. Hence, it shows that energy efficiency measure has a significant part in NZEBs and this measure should not be overlooked.

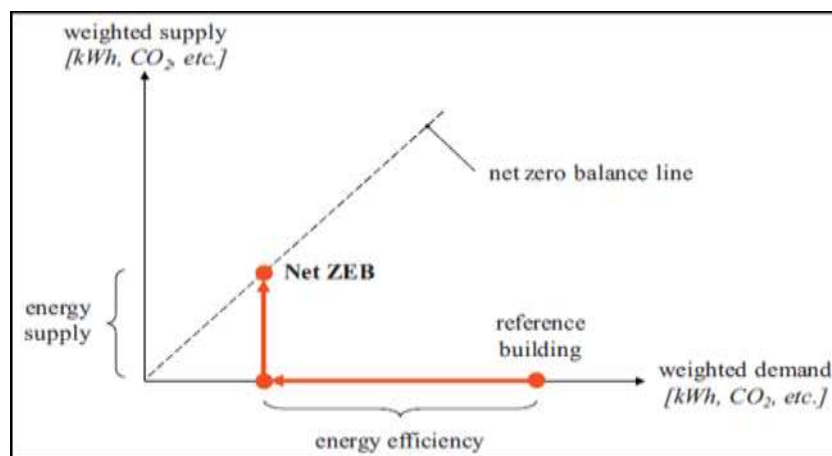


Figure 2: Graph represents the balance concept of NZEBs. Source: (Sartori et al., 2012) [17]

Thus, based on the developed NZEBs definition, NZEBs is a concept where buildings are utilised renewable energy technologies and the total energy generation from these technologies is equal to the total energy consumption of buildings over the course of a year. Other than that, NZEBs represents buildings with high energy performance and are optimally efficient.

### 2.4 Existing Green Design Practices for Healthcare Buildings in Malaysia

Integration of green design practices into healthcare buildings is crucial since little attention has been paid on greening the healthcare buildings rather than commercial buildings. At present, only a few private healthcare buildings have been assessed by using Green Building Index (GBI) rating system such as Amanjaya Specialist Center that scored ‘silver’ rating, KPJ

Ampang Puteri Specialist Hospital that scored ‘certified’ rating, Gleneagles Hospital that scored ‘gold’ rating and Columbia Hospital, Petaling Jaya that scored ‘certified’ rating [19]. Even though the green healthcare buildings in Malaysia is still limited, but it is understood that to achieve the ‘green’ certification for healthcare buildings in Malaysia, those buildings should achieve all the criteria as required in GBI rating system.

GBI is Malaysia’s first comprehensive environmental rating system for buildings that evaluates the buildings based on the six main criteria such as Energy Efficiency, Indoor Environment Quality, Sustainable Site Planning and Management, Materials and Resources, Water Efficiency, and Innovation. This rating tools were developed by Pertubuhan Akitek Malaysia (PAM) and the Association of Consulting Engineers Malaysia (ACEM), and the tools were derived from the Singapore Green Mark, the Australian Green Star system as well as the existing rating tools to ensure the tools are practical to be use in Malaysia [20]. Besides that, GBI is a tool that can be using to evaluates the new construction buildings and existing buildings.

In regard to the healthcare buildings, there are two different types of GBI tools that are available to evaluates the buildings which are non-residential new construction (NRNC) and non-residential existing buildings (NREB) [20] [21]. GBI NRNC tool will be use for the new construction of healthcare buildings while GBI NREB tool is using to assess the existing healthcare buildings. In general, the assessment elements in NRNC and NREB tools are similar. However, the points allocated for each element is slightly different as shown in Table 1.

**Table 1: Rating system for healthcare building in Malaysia**

<b>Title</b>	<b>Version / Year</b>	<b>Elements and Points</b>
GBI NRNC	Version 1.0 / 2015	Energy Efficiency (EE): 35 Indoor Environmental Quality (EQ): 21 Sustainable Site Planning & Management (SM): 16 Material & Resources (MR): 11 Water Efficiency (WE): 10 Innovation (IN): 7
GBI NREB	Version 1.0 / 2015	Energy Efficiency (EE): 35 Indoor Environmental Quality (EQ): 21 Sustainable Site Planning & Management (SM): 16 Material & Resources (MR): 11 Water Efficiency (WE): 10 Innovation (IN): 7

By addressing the elements in GBI rating tools, healthcare buildings will be assessed thoroughly and one of key focus to design green healthcare buildings is to consider the energy require for the buildings. Maximizing the amount of natural daylight into a building could 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. [23] [24]. This view is further supported by Aelenei et al., [25], that the passive design strategies in buildings should be appropriately orientating building towards solar heating maximization when buildings are dealing with heating challenges.

Additionally, green healthcare buildings facilitate an integrated choice of building’s mechanical and electrical systems. For instance, many research have demonstrates that by implementing different energy efficiency measures in a building, the variation of energy

savings can be achieved. According to Marshall et al., [26] that carried out an investigation of the effectiveness of energy efficiency measures for different occupancy patterns. The authors 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.

Furthermore, integration of renewable energy system into green healthcare buildings is crucial in reducing the demand of non-renewable energy source. For instance, Phuangpornpitak & Tia [27] studying the integration of renewable energy in 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 to ensure that it can be used thoroughly and commercially.

Therefore, to obtain the ‘green’ certification for healthcare buildings, these buildings should be designed with the integration of renewable energy share as well as utilising energy efficient technologies so that the energy required to operate this building will be reduce. There are many different types of literature reviews, each with its own approach, analysis, and purpose. Through rigorous review and analysis of literature that meets specific criteria, the systematic review identifies and compares answers to health care related questions.

### 3. Methodology

The purpose of this section is to describe the methods that were used for this paper. The semi-structured interviews were employed in this paper and respondents comprises of architects were interviewed to explore the current green design practices for healthcare buildings in Malaysia that has been carried out as well as their understanding on NZEBs. The summary data gathering process is illustrated in Figure 3.

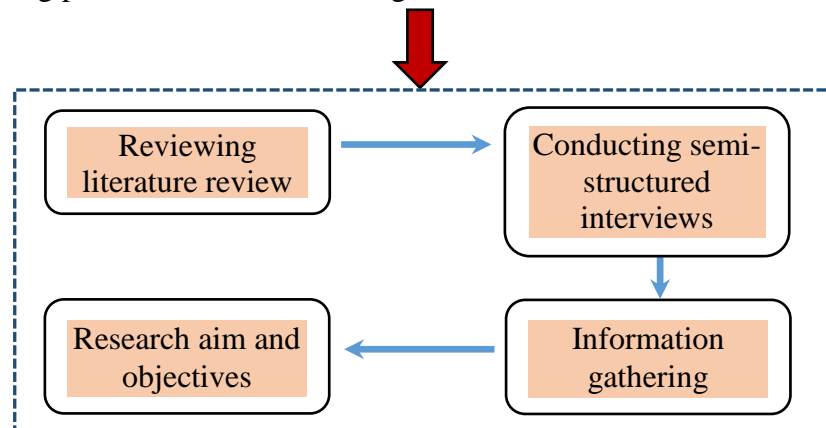


Figure 3: Data gathering process

#### Interview Data Collection

A semi-structured interview was chosen for this study since there is a limited literature on the current green design practices for healthcare buildings in Malaysia as well as NZEBs application in Malaysia. Therefore, the focus of these interviews is given to getting an understanding on the green design for healthcare buildings that been practiced in the Malaysian construction industry. In addition, the interview sessions that have been conducted are important to ensure that all current green design practices for healthcare buildings in

Malaysia are captured, despite simply relying on the literatures. Moreover, the “face-to-face” method of interviews will be undertaken for this study. The selections of places for interviews were decided by interviewees, and each of interview took approximately 30 to 60 minutes to complete.

Furthermore, the interviewees were assigned codes as R1, R2, and R3. Besides that, to ensure the quality of the interviews, all respondents required to be active in Malaysian construction industry and had direct involvement in the buildings projects located within Malaysia. The key profiles for the interviewees are shown in Table 2.

**Table 2: Key profiles for interviewees**

Item	R1	R2	R3
<b>Position</b>	Architect	Architect	Architect
<b>Organization</b>	Consultant	Consultant	Developer / Client
<b>Experience</b>	More than 5 years	More than 5 years	More than 5 years

As for the interviews, the objective of this paper will be involved to acquire the architect’s views on the current green design practices for healthcare buildings in Malaysia as well as their ideas on NZEBs application in Malaysia.

#### 4. Findings and Discussion

Generally, the interviews results have showed that green design practices for healthcare buildings in Malaysia emphasizes several numbers of features which involve reducing energy use, improving buildings facades, the selection of buildings materials, utilisation of passive solar heating and cooling, the utilisation of energy efficiencies systems as well as renewable energy share in the buildings. These practices have some common with NZEBs design practices even though there are still no specific design strategies in achieving NZEBs design, but based on Yuehong *et al.*, [28] there are several common design elements and some consensus in designing NZEBs.

According to Aelenei *et al.*, [29] and Yuehong *et al.*, [28], there are three main steps of a design approach that can be applied in designing NZEBs which are the first design approach is a 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 is also crucial to be taken in designing healthcare buildings since these approaches able to succeed in reaching the desired energy performance as well as NZEBs target.

The results of this study indicate that passive approaches are one of the significant element in designing green healthcare buildings in Malaysia since this approach will affect directly to the energy needs for the buildings. These findings further support the study of Alessandra *et al.*, [30] 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 [31].

Furthermore, some of the interviewees have highlighted that an architect is responsible to ensure some elements of passive approach should be carried out to support the sustainability in construction. These results match those observed in earlier studies such as Gandhi *et al.*,

[32] stated that architects have an important role in controlling aspects of a passive design when designing NZEBs. Some of the interviewees have responded that:

When designing a healthcare building, an architect is compulsory to follow the standard specification and requirements that have been set by the government. However, an architect can propose some sustainable materials to be applied when designing the healthcare buildings. (R1)

For design and build projects, an architect is encouraged to apply some sustainable elements into passive approaches such as materials selections and a number of ventilations for the buildings. (R2)

Moreover, according to Thalfeldt *et al.*, [33] when designing NZEBs, façades have 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 to prevent overheating in a building [25]. Therefore, it is important to consider passive approach while designing green healthcare buildings as the amount need of artificial light in the building needs will be reduced, hence it will create a pleasant environment.

In regard to the utilisations of energy efficiency system, the interviewees have emphasized that the pathway towards green healthcare buildings is by considering of energy efficiency measures. Besides that, 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 [34]. 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) [35]. One of the interviewees has indicated the importance of energy efficiency system in healthcare buildings

As an architect, we have emphasized the importance of energy efficiency measure for this healthcare building since this measure is much easier to be applied rather than the passive approaches and these measures do not relates to any hygienic condition requirements. (R1)

Moreover, in relation to the availability of energy efficiency technologies in Malaysia, there are no problems to obtain the technologies since Malaysia is one of developing countries (R2, R3). However, the cost for these technologies is quite high and for that reason, most of the developers are not fully utilised the application of energy efficiency technologies in buildings (R3). Similarly, based on Jonas *et al.*, [36] which investigated barriers that prevent energy efficiency adoption in multifamily buildings in Sweden and authors proposed a novel categorization framework for barriers to energy efficiency in buildings. The results showed that barriers related to contextual level are the most significant to prevent energy efficiency adoption. The contextual level is characterized as the rules and regulations that influence technological design and market development.

Thus, based on the findings and the arguments, energy efficiency measure in a building is vital towards designing a green healthcare building in Malaysia since energy savings in 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 [17].

Additionally, the utilisation of renewable energy share in the buildings is also important towards designing green healthcare buildings in Malaysia. These results are similar with



NZEBs design approached since the necessity of renewable energy systems is vital towards NZEBs to reduce and as well as to offset the thermal energy need in buildings. NZEBs should also be designed with the balances energy requirements between active energy production techniques and renewable technologies to achieve the NZEBs objective [37]. For designing a green healthcare building, it is important to consider renewable technologies as part of the building since the utilization of renewable energy systems in buildings can be a critical need and solutions against global warming and environmental pollution [38].

As a result, since renewable energy system is crucial towards green healthcare building and there is a lot of benefits that can be gained through these systems, the renewable energy systems should be utilised properly when designing a healthcare building. Therefore, through the application of renewable energy technologies to support green healthcare building, it is able to reduce the dependent on non-renewable energy and thus, a greener environment can be achieved. The Summary of NZEBs practices and benefits are shown in Table 3.

**Table 3: Summary of current green design practices for healthcare buildings in Malaysia**

<b>Green design practices</b>	<b>Key points from interviewees</b>	<b>R1</b>	<b>R2</b>	<b>R3</b>	<b>Similarity with NZEBs design practices</b>
<b>Passive approaches</b>	Sustainable Materials	√	√	-	Maria et al. [39];
	Buildings Orientation	√	√	√	Fabrizio et al. [40];
	Shading Devices	√	-	√	Cristina et al. [41];
	Buildings Ventilation	√	√	√	Edwin et al. [42];
	Daylighting	√	√	√	Fausto et al. [35]
	Thermal Insulation	-	-	√	
<b>Energy efficiency technologies</b>	LED Lightings	√	√	√	Niki et al. [43];
	Lighting Automation	-	√	-	Dalla et al. [44];
	Energy Star	√	√	√	Annamaria et al. [45];
	Appliances				Fabrizio et al. [46]
<b>Renewable energy systems</b>	PV Systems	√	√	√	Jarek et al. [47]; Becchio et al. [48]; Zhiyong et al. [49]; Ayman et al. [50]; Ajla Aksamija [22]

#### 4. Conclusion

The present study was designed to explore on the current green design practices for healthcare buildings in Malaysia towards NZEBs. This study is important to support the government initiative to transform the construction industry to be environmental sustainability as stated in Construction Industry Transformation Programme (CITP) 2016-2020. This study showed that the current green design practices for healthcare buildings in Malaysia involve three main design practices which are passive approaches, energy efficiency technologies, and renewable energy systems. Besides that, one of the more significant findings to emerge from this study is that some of the current green design practices for healthcare buildings in Malaysia are common with NZEBs design practices. This shows that although NZEBs concept in Malaysian construction industry is still considered new and it needs to be explored, but some of the green practices that has been carried out in the Malaysia construction industry are able to be applied in the NZEBs concept. This paper makes several noteworthy contributions to the construction players to design

NZEBs healthcare buildings in Malaysia in the future. However, a limitation of this paper is that the numbers of respondent were relatively limited. It is recommended that further research to be undertaken with more numbers of respondent to get more comprehensive findings as well as representable to the whole Malaysia context.

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