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Comparative Study of Six Green Building Rating Systems in Asia: Focusing on Energy and Water Conservation

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ABSTRACT

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The huge consumption of energy and water in the construction sector has become a major concern. Currently, the green building rating system is considered as an effective method to achieve more sustainable construction practices. Many Asian countries have developed green building assessment tools concerning the efficiency of water and energy usages in buildings.

The aim of this thesis was to compare and discuss how energy and water aspects are evaluated in Asian green building rating systems. In this study, criteria schemes of six Asian rating systems were analysed to understand the role of energy and water.

It was found that energy receives the highest position in the weighting of categories of all six rating tools. In contrast, the attention for water is less significant. The results indicated some criteria that most systems have in common. Moreover, they also pointed out some system-specific criteria that have been considered by only a few rating systems such as building automation system and water consumption during the construction phase.

It is suggested that more research need to be carried out to include assessment criteria during the construction phase. In addition, Asian green building rating systems need to give more emphasis on water and update the criteria schemes with recent innovations and technologies.

Key words: green building rating system, Asia, water, energy, sustainable development

CONTENTS

ABBREVIATIONS AND TERMS

BAS	Building Automation System
BREEAM	Building Research Establishment's Environmental Assessment Method
CASBEE	Comprehensive Assessment System for Building Environmental Efficiency
GBI	Green Building Index
GBRS	Green Building Rating System
GHG	Greenhouse Gas
GRIHA	Green Rating for Integrated Habitat Assessment
HVAC	Heating, ventilation, and air conditioning
IEQ	Indoor Environmental Quality
IGBC	Indian Green Building Council
LEED	Leadership in Environmental and Energy Design

1 INTRODUCTION

The construction industry plays a crucial role in human's activities which satisfies the basic needs of society, enhances life quality and contributes to economic growth. Nevertheless, the building industry has a detrimental effect on the environment. Yılmaz and Bakış (2015) stated that 40% of the global solid waste is generated by the building sector. The construction activities also contribute 30% to the total greenhouse gas (GHG) emission (UNEP 2009). Moreover, buildings are consuming a large amount of natural resources. It has been reported that building blocks production consumes around 40% of the total energy consumption as well as 17% of the total freshwater withdrawals (Say & Wood 2008; WBCSD 2008). Energy and water are essential resources for human life and economic activities. However, freshwater and energy scarcities have become a global concern due to the overpopulation (Singh, Singh & Srivastava 2017, 7; Nanda & Pring 2013). Thus, it is imperative to manage water and energy consumption in buildings.

The term "green building" has become more and more popular lately. It is a building that abides with specific performance requirements to reduce its adverse impacts on the environment (World Green Building Council n.d). As an effective method to tackle environmental challenges, a rapid increase has been observed in the figure of green building assessment tools in the last few years (Cole, Howard, Ikaga & Nibel 2005). Energy and water are one of the main sustainable parameters that are often evaluated in building evaluation tools together with site aspects, indoor environmental quality (IEQ) and materials.

With the advance of the construction industry across the world, a number of Asian countries have achieved remarkable improvements in the path to their sustainability with the many efforts to remediate environmental impacts. According to Shen (2016), green buildings in Asia have grown significantly recently. Many countries in the region have developed their own national green building rating systems (GBRS). The number of certified and registered buildings is increasing year by year. However, there are still existing barriers which require further developments to improve the efficiency of rating systems in reality.

One of the major methods to refine existing assessments tools is identifying the strengths and weaknesses by comparing their criteria (Shamseldin 2016). The purpose of this study is to compare and contrast the green building rating systems in Asia with a focus on energy and water criteria by reflecting on key environmental parameters and identifying the strategies used for water and energy conservation. As a part of the sustainable use of resources, the importance of water and energy will be discussed and the credentials admitted for water and energy aspects in the green building rating systems will be evaluated. The results can be used as a material for further developments of green building rating systems or as a referenced document for building operators.

2 BACKGROUND

2.1 Green concept and green building rating systems

“Green buildings” or “sustainable buildings” is no longer a new term, which refers to structures that preserve natural resources and are environmentally responsible. From the designing phase, the construction process to the operation, a green building aims to ensure the least effects on the environment. Some typical features of a green building include the utilization of renewable energy, efficient use of resources, reduction of waste and pollution, facilitation of a good level of indoor air quality, consideration of using sustainable and ethical materials as well as the endorsement of environmentally friendly design, construction and operation. (World Green Building Council n.d.)

According to the figures from the World Green Building Council, an efficiently designed green building is likely to reduce 30% to 60% of the energy produced by a regular building. Green buildings receiving Green Star certification in Australia are presented to emit 62% less GHG emission and decrease 51% of potable water used. (World Green Building Council n.d.) Moreover, green buildings also have positive impacts on the economy and society. A well-planned green building has a longer lifespan which reduces operation and management costs and minimizes risks to human health and the environment (Sev 2009a). Attaching the sustainable label into buildings can become a useful market tool for building owners and motivate the innovation of green techniques.

There are numerous of criteria-based rating tools for buildings, which are often known as green building rating systems (GBRS). The evaluation frame of a rating system is often divided into categories such as site aspects, energy, water, materials aspects, indoor environmental quality, and innovation. Each category contains a number of criteria presenting the specific requirements or commitments needed to be achieved. Points are allocated to each criterion. Buildings are awarded points when fulfilling the corresponding criteria. The total point and the points given for each criterion are different depending on each GBRS. The certification level of a building is determined according to the total point acquired.

Green building assessment tools have been established for several types of buildings such as residential buildings, non-residential buildings, new constructions, commercial buildings, hospitals, schools. Depending on the features, the requirements for each building type are different. (Alyami & Rezgui 2012; Ali & Al Nsairat 2009.)

In the last decade, a large number of GBRS have been developed. Among those, the most popular systems in the world that can be mentioned are BREEAM and LEED. BREEAM (Building Research Establishment's Environmental Assessment Method) is the first established assessment tool for buildings in the UK with the aim to reduce the impacts of buildings on the environment (BREEAM 2011). In 1998, LEED (Leadership in Environmental and Energy Design) was introduced in the US (USGBC 2013). It has become the most widely used rating tool. Over 38,600 projects from more than 167 countries and territories have been certified with LEED, reflecting its popularity around the world (Xu, Choy & Mackres 2017). According to Gowri (2004), LEED and BREEAM have influences on a great number of GBRS developed later. LEED India, BREEAM Canada or BREEAM Greenleaf are some examples. These standards have been modified and integrated based on LEED and BREEAM. Other well-known GBRS that can be named include Green Star of Australia, Green Mark of Singapore, EcoProfile of Norway, Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) of Japan or BEAM Plus of Hongkong.

Even though, some assessment tools are widely accepted with high recognition, developing new rating tools is still essential for each country because of specific environmental conditions, building types and other factors (Kim, Myoung & Jeong 2013). On the other hand, existing assessment tools also need to be updated in consideration of the latest regulations and technologies. For instance, the pilot version of LEED for new construction which is LEED 1.0 was introduced in August 1998. Since then, several versions have been released. The latest version, LEED v4.1 was published in January 2019.

The rating system is a framework which is used to evaluate environmental performance and sustainable development of construction. At the same time, it is also an effective design tool for operators to determine priorities, strategies, and

goals in the planning phase of a building. The emphasis of a rating tool on different aspects can affect the decision-making processes. Hence, investigating green building rating systems is especially essential for the development of the building sector. (Retzlaff 2008.)

The reliability of green building rating systems can be limited due to some practical issues in the construction industry. Because of technical difficulties and attempts on meeting the requirements of the rating certification, it can become too overwhelming for the operators which prevents them from exploring for better solutions (Ding 2008). For instance, if the operators only focus on fulfilling the requirements of the selected rating tool, other aspects which are not addressed can be neglected. According to Conte & Monno (2012), in the worst case, the green certification became an advertising tool for marketing like a checklist to be filled rather than a guide to save resources and improve environmental performances. The scenario might cause a reserve effect on the current development of the sustainable building industry as the “green features” of the buildings are not guaranteed to bring benefits to the environment. On the other hand, the operators can make a profit out of the reputation of the green labels. Analyzing and comparing among different rating systems is a way to detect restrictions and improve the efficiency of assessment tools.

2.2 Green building rating systems in Asia

The concern for environmental issues, national energy security, and other factors have increased the motivation to apply sustainability methods in the construction industry within Asia (BCI Asia 2014). The efforts from the governments as well as other individuals and organizations lead to the establishment of numerous green building assessment tools and the increase in the figure of green buildings. As a result, the impacts on the environment will be minimized and improved.

In 2002, when the World Green Building Council (WGBC) was founded to act as a global connection for green building councils, there were no nations from Asia. At present, WGBC has around 100 member nations and 14 of them are from Asia (World Green Building Council n.d). A large number of rating tools have been

introduced by Asian countries in the past few years (figure 1). Some countries have developed more than one domestic rating scheme such as Japan and India. The reputation of Asian rating systems has increased internationally. The evaluation standard from Singapore, Green Mark is the first rating tool applicable to the tropical zone (Hordeski 2011). The differences in climate affect many aspects of a building such as the energy consumption for heating or cooling, the indoor temperature. The most prominent standards in the world, LEED and BREEAM, were all developed by countries locating in the temperate zone. Thus, Green Mark might be a more appropriate rating tool for tropical countries. It has gained popularity among South East Asian countries, China and India attracting building owners to apply for Green Mark certification (Cheam 2015).

Despite the emergence of local rating tools, the most well-known green building rating system, LEED still receives high recognition in this region with almost 6000 projects registered and over 2000 projects certified in 18 Asian countries (Shen 2016). Additionally, India has developed its own LEED version which is LEED India in 2013 reflecting the popularity of the US rating system. However, this study concentrates on domestic rating systems which are developed by Asian countries. Hence, LEED will not be considered.

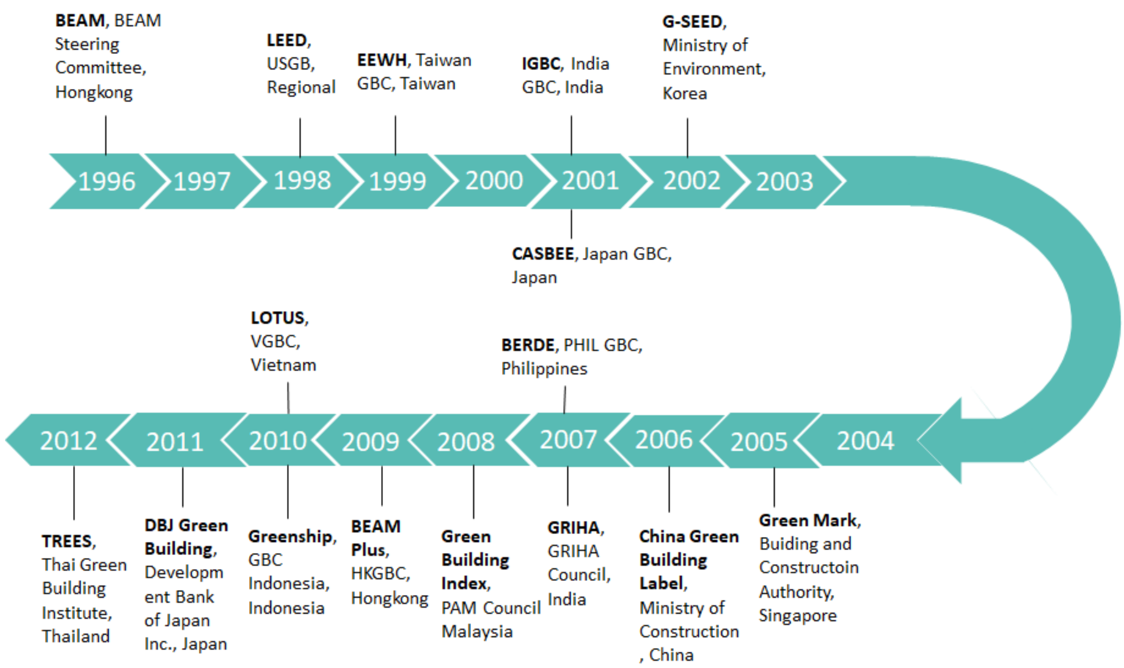

FIGURE 1. Green Building Rating Systems Establishment in Asia (BEAM was rebranded as BEAM PLUS in 2009)

As stated by Shen (2016), a growing number of policies regarding green buildings has been launched by national or municipal governments including goals, plans, and legislation. The target of the Singapore government by 2030 is to have 80% of their building stock certified by their rating tool, Green Mark (excluding industrial facilities and logistics). This goal is set with a framework of legislation which obligates new facilities to be certified with Green Mark and be re-certified after three years as existing buildings. Moreover, any heating, air conditioning or ventilation upgrades of an existing property also need the Green Mark certification. The Green Building Action Plan was implemented by the Chinese government in 2013. It requires all public constructions including public residential buildings and commercial buildings that have more than 20.000 sqm gross floor area to acquire at least one-star rank certified by the China Green Building Evaluation Standard. Additionally, energy efficiency retrofits will be required in existing residential and commercial properties. In India, the government is the pioneer by having their own buildings certified with the domestic rating tool developed by the Indian Green Building Council (IGBC). There are over 850 buildings that received certification from IGBC. The Delhi Metro stations achieved Platinum certification – the highest level from IGBC Metro. (Shen 2016.)

Figures are reflecting a positive progression of green buildings in Asia. According to Hill (2017), Singapore has a quite high percentage of green buildings which is 30% out of the total figure. This reflects the effort of the Singapore government in achieving the goal which is having 80% of the total construction certified by Green Mark (Shen 2016). Other cities are catching up such as Beijing (11%), Shanghai (15%) and Tokyo (8%). However, compared to other cities like London and Paris which have a remarkable percentage of green buildings, 68% and 64% respectively, Asian cities still need a lot of improvements and developments.

Besides, it is also essential to ensure the practical matters of green building rating systems. Shen (2016) stated that a great number of certified green buildings in Asia have been evaluated with rating tools that measure only the design and construction phase without assessing actual performance. To be specific, a hefty figure of 93,7% of the total green buildings in China were evaluated only with design standards in 2014. It is a huge restriction that diminishes the efficiency and the reputation of Asian assessment tools.

2.3 The importance of energy and water in the sustainable development of the construction industry

Since the construction sector contributes significantly to the economy and affects greatly the environment and society, it has become imperative to practice sustainable development in the construction industry. Different from the traditional design which tends to focus on cost and quality matters, sustainable design concentrates on the reduction of natural resources consumption and minimalization of environmental degradation (Sev 2009b). Therefore, the conservation and protection of natural resources including water and energy need to be addressed and discussed properly in green building assessment tools to ensure a more sustainable building industry.

Singh et al. (2017, 7) described that the population explosion has caused rapid growth in total energy consumption. The global demand for energy has been increased by almost 85% within the past 30 years meanwhile, concerning only Asia, the figure is over 300% (Energy Information Administration 2001). As a result, energy efficiency has become one of the top priorities nationally and internationally. Moreover, energy efficiency is also deemed as an effective tool to reduce greenhouse gas emissions. The primary GHGs such as carbon dioxide are generated from fossil fuel combustion while 80% of global energy is yielded fossil fuels (Zimmerman 2012; Lu 2017).

As a crucial resource for the building industry, energy is involved in a large number of construction activities such as manufacturing, transporting and extraction. It is also essential for heating, cooling, lighting and other electrical equipment. The study of Lombard, Ortiz & Pout (2008) reveals that the energy consumption of residential and commercial buildings is much higher than that of other industries and transportation. In developed countries, the number varies from 20% to 40% out of the total energy consumption. Since the construction industry is a large consumer of energy, the development of green buildings is one of the most efficient approaches to solve the energy issue and reduce negative impacts on the environment. On the other hand, saving energy has numerous benefits to society and it is an important step to achieve sustainability requirements in green buildings. Energy conservation means the costs used for energy production are

minimized. In addition, the air quality and the environment condition will be improved when GHG emissions are reduced.

Freshwater that is usable for human daily activities is a limited source. The rapid growth of the world population also results in an increasing demand for water. As an essential resource for human life, the demand for water is rising by 64 billion cubic meters per year (Nanda & Pring 2013). According to Das, Bera, and Moulick (2015), 5 billion people which accounts for two-thirds of the population will suffer from clean water scarcity in 2050. With this inclination, water shortage is inevitable and the water cost will increase as all freshwater resources will be exhausted.

The building sector is one of the largest consumers of water along with energy (Guggemos & Horvath 2006). Water is used in different stages of a building. Rahman et al. (2019) mentioned that activities in the excavation phase such as soil compacting, preparation of mortar, mixing of cement, construction sites cleaning and demolition require a remarkable amount of water. During the operation phase of a building, a tremendous volume of water is needed for human daily activities such as drinking, toilet flushing, washing, and gardening. From all facts stated above, it is crucial to manage the water performance of the building industry.

3 LITERATURE REVIEW

Developing a new evaluation tool or improving an existing one requires analysing the strengths and weaknesses of current evaluation tools which can be based on three major ways: numerical statistics acquired through actual performances of green buildings, feedbacks, and reviews from the green building professionals and the comparisons of different rating systems. The most common method is the comparative analysis which is a useful approach to integrate rating systems information in short time duration (Shamseldin 2016). Quite a few comparative studies on green building rating systems have been conducted in recent years. This section will focus on reviewing the existing literature related to the research topic and identifying the future research direction.

In order to gain a comprehensive view of previous comparative studies in the related topic, a total of 17 studies from 2008 to 2018 were reviewed. As there is a great number of green building assessment tools, the subjects of researches are diverse. The purposes and methodologies of studies will be the key focuses.

There is not a standard framework for the comparative analysis among green building rating systems. The compared aspects vary depending on the aim of each study. However, according to the papers and structures of green building rating systems, the research methods are divided into three levels. The general comparison level refers to the background information of the assessment tools such as developers, history. Category comparison level covers the measurements and evaluations regarding the categories such as management, energy, transport, water, waste, and materials. Criteria comparison level compares the requirements in each category, for instance, the total building energy consumption and the potable water reduction.

The summary of the reviewed literature on this topic is demonstrated in figure 2. LEED is the most popular assessment tools among the studies followed by BREEAM and CASBEE. Within local rating tools from Asia, CASBEE and Green Mark are the most studied rating systems. The purposes of studies are different but most of them aimed to identify similarities and differences among GBRS.

Some studies concentrate on specific issues leading to a comparison of a certain category in green building assessment tools. A minor number of comparative studies intends to develop new tools.

References	Green building rating systems included																				Purpose of study			Method		
	BREEAM (Great Britain)	LEED (USA)	ITACA (Italy)	GREEN GLOBES (USA, Canada)	GBTool (Canada)	GG (Canada)	ESGB (China)	GBAS (China)	BEAM (Hong Kong)	CASBEE (Japan)	KGBCC (South Korea)	GREENSHIP (Indonesia)	GBI (Malaysia)	GREEN MARK (Singapore)	GREEN STAR (Australia)	DGNB (Germany)	LOTUS (Vietnam)	TREES (Thailand)	BERDE (Phillipines)	GRIHA (India)	Finding similiarities and differences	Creating new evaluation standard	Focusing on particular issues	General comparison	Category comparison	Criterion comparison
Lee & Brunette (2008)	x	x							x														x			x
Papadopoulos & Giama (2009)	x	x																			x			x		
Mao et al. (2009)	x	x			x		x			x				x							x			x		
Ali & Al Nsairat (2009)	x	x			x					x												x			x	
Yu & Jeong (2011)	x	x							x														x			x
Nguyen & Altan (2011)	x	x							x	x					x						x			x		
Alyami & Rezgui (2012)	x	x			x					x											x			x	x	x
Vyas & Jha (2012)	x	x						x							x	x				x	x			x		
Ahankoob et al. (2013)		x												x							x			x	x	x
Bahaudin et al. (2014)		x									x	x	x	x							x			x	x	
Schwartz & Raslan (2013)	x	x																					x	x		x
Stankovic et al. (2014)	x	x								x													x			x
Asdrubali et al. (2015)		x	x																		x			x	x	
Chen et al. (2015)	x	x					x		x	x													x	x	x	x
Yu et al. (2015)	x	x								x												x			x	x
Wu et al. (2016)	x	x				x	x																x			x
Luangcharoenrat & Intrachooto (2018)	x	x										x	x			x	x	x	x		x				x	

FIGURE 2. Summary of the reviewed literature

Most of the studies assess only one or two levels of comparison. There are only three out of 17 studies comparing all three levels. This is due to the difficulty in evaluating GBRS and the inconsistency of different assessment tools. Even though the researches of Alyami and Rezgui (2012), Ahankoob et al. (2013) and Chen et al. (2015) conducted all levels of comparison, the numbers of rating systems in the analyses are limited (from two to five systems). Moreover, the authors did not investigate the categories or criteria particularly but only providing general discussion and conclusion. Since there is a huge amount of data in each GBRS, the authors need to minimize the comparing aspects if they want to compare more systems at the same time or concentrate on specific parameters. For example, Luangcharoenrat and Intrachooto (2018) were able to analyse eight GBRS together focusing only on category comparison. In addition, the difficulty in comparing rating systems associating with a large number of criteria was also

demonstrated by Li et al. (2017). According to the research, in most comparative analyses, there are two to five green building assessment tools being measured. Only a trivial number of studies evaluated more than six rating systems.

There are four analyses concentrating on specific categories and discussing how GBRS evaluates those aspects. Lee and Brunette (2008) conducted a study to investigate the assessment methods of BREEAM, LEED, and HK-BEAM (BEAM Plus) concerning energy usage. The research provided a detailed comparison of criteria used under the energy category. Moreover, the authors also assessed actual energy performances of the buildings certified by three GBRS to discover the differences between evaluation standards and real statistics. Meanwhile, the study of Schwartz and Raslan (2013) compared computer-based tools using for the energy consumption prediction. The analysis focuses on technical issues and their effect on energy performance in different assessment tools rather than determining the contrast among rating systems. Besides energy, waste management and indoor air quality had also been investigated in two different studies. Wu et al. (2016) analyzed the waste management requirements by comparing five GBRS whereas "Indoor Air Quality" (IAQ) category in green building assessment tools were reviewed in the study of Yu and Jeong (2011).

Depending on the reviewed literature, it is necessary for future studies to provide more specific comparisons of green building rating systems. There were only a few researches focusing on a certain category such as energy, IAQ or waste management. Assessing other categories is also essential for further appropriate developments of existing assessment tools. As mentioned above, LEED and BREEAM are the commonly studied rating systems. In general, standards from developed countries were studied more than those from developing countries. Hence, more researches on GBRS from developing countries need to be carried out. Despite the difficulties in comparing a lot of rating tools, a greater number of assessments tools involved will provide a more comprehensive judgment. Thus, the number of rating systems in the analysis also needed to be taken into consideration to increase the credibility of the research.

4 RESEARCH METHOD

4.1 Research methodology

The research methodology is a crucial element as it determines the procedure and the direction of the research. Wisker (2001, 65) explained that the selected approach can indicate the range of logics behind the study. As stated by Collins (2010, 38), the research method depends on the research philosophy. Interpretivism and positivism are two philosophies mostly used by researchers. Positivists give prominence to scientific quantitative methods while interpretivists prefer humanistic qualitative methods to their studies.

Qualitative and quantitative methods are 2 popular approaches which have been used widely in academic studies. Qualitative research aims to explore and understand the meaning of a problem or individual by collecting non-numerical data such as participant observation. It is used to investigate opinions, attitudes, and behaviours that usually involving participants in the data collection. Quantitative research uses data in numerical form which can be measured or categorized to quantify a problem. It depends on measurements and statistical analyses to conclude a matter. (McLeod 2017.)

This thesis “Comparative Study of Green Building Rating Systems in Asia” uses data collected from the manual documents of the green building assessment tools. Analyses and conclusion are based on facts and figures acquired. Thus, this research employed the quantitative methodology.

4.2 Data collection and sampling criteria

The aim of this thesis is to indicate similarities and differences in water and energy categories among Asian green building rating systems. Since there are a large number of existing GBRS, a screening procedure was conducted to enhance the comprehension of the analysis. The study adopted the selection crite-

ria utilized by Wu et al. (2016) with some adjustments to identify appropriate rating tools used in this study. The screening process includes three criteria. Firstly, the availability and the sufficiency of the documents were considered (Wu et al. 2016). There is only a number of standards that provide free access to the manual documents while others require purchase or license to obtain. This was the prior criterion since the study has a concentration on specific categories of the rating tools which are water and energy. It is crucial that related documents provide sufficient and explicit pointing frames to carry out a subsequent comparison.

The relevance is the second criteria when selecting versions to be analysed. GBRS can be developed for various types of building. In many rating systems, non-residential buildings and residential buildings are assessed using different versions. While residential building refers to only places with sleeping accommodation, non-residential building covers all other types of buildings such as offices, commercial buildings and industrial buildings. In this study, assessment tools for non-residential buildings were employed instead of residential buildings to enhance the comprehension of the analysis. However, there are some rating tools which did not develop a specific version for non-residential buildings. Thus, other versions which are also applicable to non-residential buildings were utilized. The last criterion is that the assessment tools need to have measurable credits given for categories. To be specific, criteria and requirements in each category are assigned with a certain number of points. It ensures the applicability of quantitative comparison. (Wu et al 2016.)

The primary data is the data obtaining from first-hand sources. To enhance the reliability and the accuracy of the analysis, primary data collecting from the official website of the green building assessment tools were utilized. Additionally, the study took into consideration only the versions that have been used for certifying. The versions which are being published for consultancy and have not been implemented yet will not be included as they can still be modified which will affect the results of the analysis.

After screening all the criteria, there were six rating systems selected in this study. The information on selected green building rating systems and document referred are demonstrated in table 1.

TABLE 1. Summary of GBRS

No.	Green Building Rating Systems	Country	Document
1	BEAM Plus	China (Hongkong)	EB 2.0 (2016)
2	BCA Green Mark	Singapore	NRB 4.1 (2013)
3	GBI	Malaysia	NREB 1.1 (2011)
4	LOTUS	Vietnam	NR 2.0 (2015)
5	BERDE	Philippines	NC 2.2.0 (2018)
6	GRIHA	India	Volume 1 (2010)

4.3 Analysis technique

Three stages of comparison were analysed in this comparative study. The research covered from general to specific information of green building rating systems. Firstly, the general comparison was conducted including basic information such as the number of categories, certification level, developers and histories. This section provides fundamental knowledge of the selected rating systems. Following that, the emphasis on categories was compared. As explained earlier, assessment tools use the point system to measure building performances. Each criterion is evaluated with points. The point of a category is the total point of all criteria stated under that category. Based on that, the percentage that each category accounts for in the total point of the system were calculated and compared. The weightages of energy and water categories are the key focus.

Last but not least, a criteria comparison was carried out. There are different criteria for buildings within a category. The criteria used under water and energy categories were reviewed and summarized for all six selected GBRS. The existence of criteria in each rating tools was analysed to discuss the credentials given for water and energy categories.

There are plenty of criteria and categories and each assessment tools divide the criteria and categories in a different way. Therefore, criteria including the same requirements were grouped as one criterion. Categories which assess the same criteria were considered as similar categories.

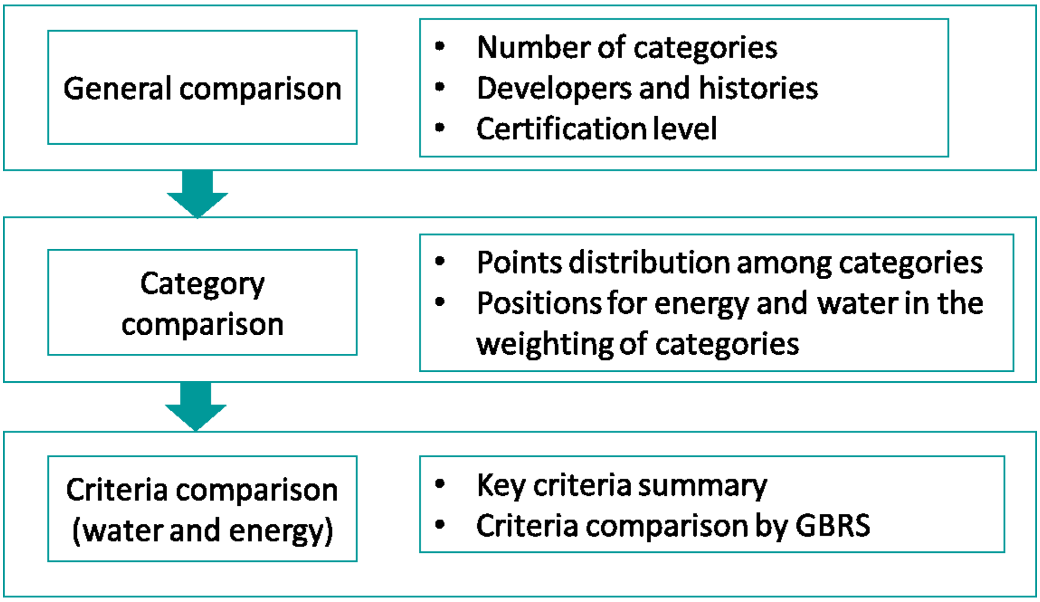

FIGURE 3. Analysis framework

5 RESULTS

5.1 Overview of chosen Green Building Rating Systems

Main features of six selected green building rating systems including developer, year of establishment, assessed categories and certification level were summarized in table 2.

BEAM Plus was developed by the Hongkong Green Building Council Limited (HKGBC) in 2009. However, its precursor was HK-BEAM founded in 1995 by the Real Estate Developers Association of Hong Kong, Planning Environment and Lands Bureau, Swire Properties, Hongkong Land, Hong Kong Polytechnic University and Business Environment Council making BEAM Plus to be the first local green building rating tools in Asian. In the analyzed version of BEAM Plus (EB 2.0), there are seven categories which are Management, Site Aspects, Material and Waste Aspects, Energy Use, Water Use, Indoor Environmental Quality, Innovations, and Additions. (HKGBC 2016.)

In 2005, Green Mark was introduced by the Building Construction Authority of Singapore. There are five key assessments for this standard including Energy Efficiency, Water Efficiency, Environmental Protection, Indoor Environmental Quality, and Other Green Features and Innovation. (BCA 2013.)

Green Building Index (GBI) is the rating tools launched by PAM (the Association of Architects in Malaysia). Buildings are assessed with six categories which are: Energy Efficiency, Indoor Environment Quality, Sustainable Site Planning & Management, Materials and Resources, Water Efficiency and Innovation. (GBI 2011.)

LOTUS is an evaluation tool developed for the Vietnamese built market by the Vietnam Green Building Council (VGBC). The version for non-residential buildings includes nine categories: Energy, Water, Materials, Ecology, Waste & Pollution, Health & Comfort, Adaptation & Mitigation, Community, Management. (VGBC 2015.)

TABLE 2. Main features of the Green Building Rating Systems

	BEAM Plus	BCA Green Mark	GBI	LOTUS	BERDE	GRIHA
Developers	Hongkong Green Building Council Limited (non-profit organization)	Building and Construction Authority (government agency)	Pertubuhan Akitek Malaysia (PAM) and the Association of Consulting Engineers Malaysia (ACEM) (third party)	Vietnam Green Building Council (non-profit organization)	Philippine Green Building Council (non-profit organization)	The Energy and Resources Institute – TERI (non-profit third party)
Year of establishment	2009	2005	2008	2010	2007	2007
Main categories	Management, Site Aspects, Material and Waste Aspects, Energy Use, Water Use, Indoor Environmental Quality, Innovations and Additions	Energy Efficiency, Water Efficiency, Environmental Protection, Indoor Environmental Quality, Other Green Features	Energy Efficiency, Indoor Environmental Quality, Sustainable Site Planning & Management, Material & Resources, Water Efficiency, Innovation	Energy, Water, Materials, Ecology, Waste & Pollution, Health & Comfort, Adaptation & Mitigation, Community, Management, Innovation	Energy Efficiency and Conservation, Water Efficiency and Conservation, Waste Management, Management, Use of Land and Ecology, Green Materials, Transportation, Indoor Environment Quality, Emissions	Sustainable Site Planning, Water Management, Energy Optimization, Sustainable Building Materials, Waste Management, Health & Wellbeing, Building Operation and Maintenance, Innovation
Certification level	Platinum, Gold, Silver, Bronze	Platinum, Gold Plus, Gold, Certified	Platinum, Gold, Silver, Certified	Platinum, Gold, Silver, Certified	1 star, 2 stars, 3 stars, 4 stars, 5 stars	1 star, 2 stars, 3 stars, 4 stars, 5 stars

BERDE (Building for Ecologically Responsive Design Excellence) was launched by The Philippine Green Building Council (PHILGBC) in 2010. The buildings were evaluated based on nine parameters of Energy Efficiency and Conservation, Water Efficiency and Conservation, Waste Management, Management, Use of Land and Ecology, Green Materials, Transportation, Indoor Environment Quality, Emissions. (BERDE 2018)

GRIHA (Green Rating for Integrated Habitat Assessment) is the national green building rating system of India from 2007. The assessment tool is divided into seven categories: Sustainable Site Planning, Water Management, Energy Optimization, Waste Management, Health & Wellbeing, Building Operation and Maintenance, and Innovation. (EARI 2010.)

The certification level is quite similar among the six rating tools. BEAM Plus, BCA Green Mark, GBI, and LOTUS has four rating levels while BERDE and GRIHA classify projects into five levels from one star to five stars. All six assessment tools determine the certification level depending on the overall score achieved.

Among six green building rating systems, BCA Green Mark is the only rating tool developed by an agency belonging to the government. This makes BCA Green Mark becomes the national rating standard from the beginning. Other rating systems were launched by non-profit organizations or third parties. GRIHA was developed by an institute without the participation of the government but later was adopted as the national standard of India. The differences in the development are due to the policy of each country and territories. Under the perspective of market-penetration, it cannot be denied that BCA Green Mark is gaining popularity beyond Singapore leading to more application registered in South-East Asian countries, China, India and the Middle East (Cheam 2015). According to Ives (2014), the growth of BCA Green Mark can be a challenge to the development of LEED in Asia. Developing by a government agency, BCA Green Mark has a huge advantage in promoting and marketing.

5.2 Category comparison

From the overview of six green building rating systems, it is clear that the number of categories and the evaluating aspects are different in each GBRS. Some common categories assessed by a major number of rating systems are management, site aspects, energy, water, IEQ, and innovation. The percentage of the points given for each category was calculated. Table 3 reveals how the total point are distributed among the common categories. The full table displaying the point allocation of all categories can be found in Appendix 1.

Some categories which assess the same aspects were integrated. “Innovation” is the category that evaluates innovative efforts to create positive impacts on the environment. This parameter is measured under “Other Green Features” section in BCA Green Mark. Therefore, the points allocated for “Other Green Features” were counted as “Innovation”.

“Indoor Environmental Quality” category is used to measure the environment inside the building in terms of visual, thermal and acoustic. In LOTUS rating tool, internal environmental quality of the building is mentioned under “Human Health & Comfort” category while in GRIHA standard, it is assessed in “Health & Wellbeing” section. Thus, “Human Health & Comfort” and “Health & Wellbeing” are considered as the “Indoor Environmental Quality” category.

TABLE 3. Contribution of categories into the total score of Green Building Rating Systems (%)

Categories	BEAM Plus	BCA Green Mark	GBI	LOTUS	BERDE	GRIHA
Management	14,2			8,5	4	
Site Aspects	13,6	22,1	10			16,3
Energy	24,1	61,1	38	26,3	16	33,7
Water	14,2	8,9	12	11,0	14	12,5
IEQ	16,0	4,2	21	11,8	10	13,5
Innovation	7,4	3,7	10	6,8		3,8
Others	10,5		9	35,5	56	21,2
Total	100	100	100	100	100	100

From table 3, it is obvious that Energy, Water, IEQ are assessed in all building rating systems. Innovation is measured in five rating tools except for BERDE. Management and Site Aspects are considered in three and four standards, respectively.

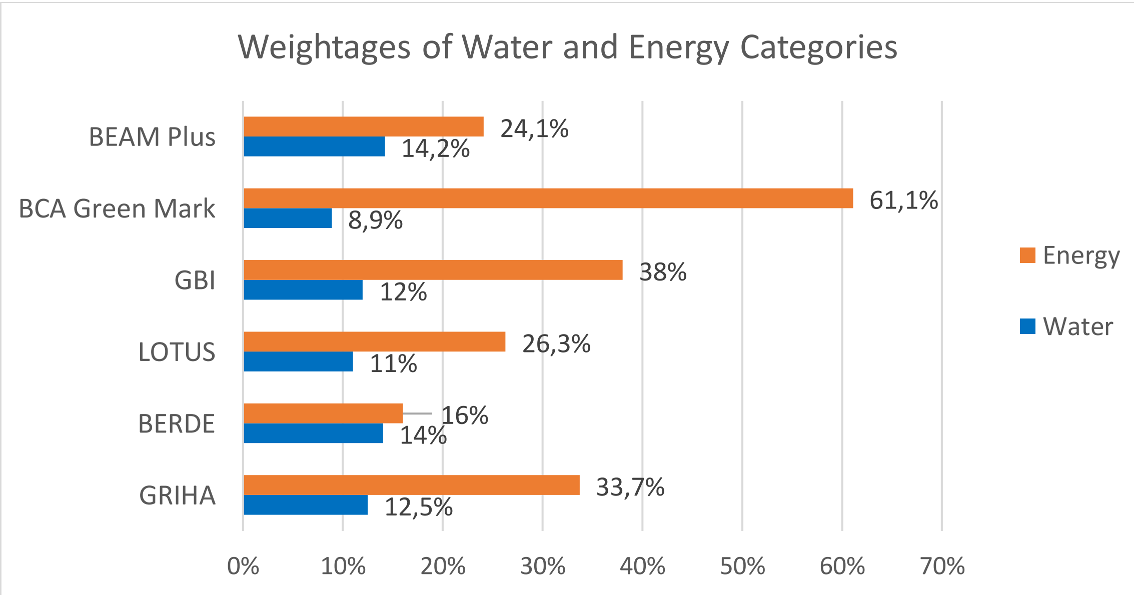

FIGURE 4. Weightages of Energy and Water Categories by GBRS

The contribution of a category in the total point of the system defines the weightage of that category. Figure 4 compares the weightages distributed for Energy and Water categories by GBRS.

Generally, the weightages of energy are higher the weightages of water in all rating tools. The percentages given for energy vary significantly. BCA Green Mark places the most remarkable emphasis on energy which accounts for 61,1% of the total point. In contrast, the lowest weightage of energy is observed in BERDE. Only 16% of the total score is addressed for energy in this system. The highest proportion of water category is 14,2% admitted by BEAM Plus rating tool. Meanwhile, 8,9% is the lowest weightage of water given by BCA Green Mark.

Although water contributes smaller percentages than energy in all assessment tools, the weightage differences between the two categories are dissimilar. The most significant gap between energy and water is 52,2% which is noticed in BCA Green Mark. It is the system giving the highest proportion for energy (61,1%) and the lowest proportion for water (8,9%). The most trivial difference between energy and water is spotted in BERDE. In BERDE rating tool, energy category comprises of 16% in the total point of the system while water accounts for 14%.

TABLE 4. Energy and Water positions in the weighting of categories

Rating systems	Energy	Water	Total number of categories
BEAM Plus	1	3	7
BCA Green Mark	1	3	5
GBI	1	3	6
LOTUS	1	3	10
BERDE	1	2	9
GRIHA	1	4	8

According to the weighting of categories, table 4 indicates the position of water and energy in the total point of the systems. In all six standards, the highest rank is belonged to energy implying the importance of this parameter in green building assessment tools. Regarding water, the priority levels given for this aspect vary slightly. In BEAM PLUS, BCA Green Mark, GBI and LOTUS, water takes the third

position in the weighting of categories. Besides energy, water also receives lower weightages than IEQ or Site Aspects in some rating tools. Only BERDE addresses Water as the second important category while the lowest position of Water is given by GRIHA. The differences in the weightage distribution of the rating systems reflect each country or territory gives the priority for different aspects.

5.3 Criteria Comparison

5.3.1 Energy Category

In this section, energy criteria are reviewed to discuss how energy is addressed in GBRS. The criteria stated under energy category are summarized and demonstrated in table 5. In the table, brief descriptions are included to explain the commitment required in each criterion.

TABLE 5. Summary of main energy criteria in GBRS

Criteria	Description
Renewable Energy	Utilizing energy obtained from renewable sources
Air-Conditioning & Ventilation System	Having an energy efficient ventilation design and air-conditioning system
Minimum energy efficiency performance	Reducing total energy consumption by enhancing energy efficiency
Energy monitoring and control	Ensuring continuous monitoring and control in buildings' energy systems
Lighting	Encouraging the use of effective lighting source to reduce energy consumption
Energy efficiency building envelope	Minimizing heat gain between the exterior environment and the building
Sub Metering and Calibration	Providing sub-metering to control the use of energy
Lifts	Encouraging the use of energy efficiency lifts and escalators
Building Automation System	Using a computer-based system to monitor building systems including heating, ventilation and air conditioning (HVAC), lighting and other electrical systems.
Commissioning	Having a plan for commissioning activities to enhance building energy performance

The existence of the main energy criteria was compared in table 6. The result indicates the similarities and differences in evaluating the building energy performance of six rating systems.

TABLE 6. Comparison of energy criteria among six GBRS

Energy criteria in GBRS	BEAM Plus	BCA Green Mark	GBI	LOTUS	BERDE	GRIHA
Renewable Energy	✓	✓	✓	✓	✓	✓
Air-Conditioning & Ventilation System	✓	✓	✓	✓	✓	✓
Minimum energy efficiency performance	✓	✓	✓	✓	✓	✓
Energy monitoring and control	✓	✓	✓	✓	✓	✓
Lighting	✓	✓	✓	✓	✓	✓
Energy efficiency building envelope	✓	✓	✓	✓	✓	
Sub Metering and Calibration	✓		✓		✓	✓
Lifts	✓	✓		✓		✓
Building Automation System	✓			✓	✓	
Commissioning	✓		✓			

It can be observed that there are some essential criteria that are required in all rating systems such as renewable energy, air conditioning and ventilation system, minimum energy efficiency performance, energy monitoring and control, and lighting. The less common criteria which are energy efficiency in building envelope, sub metering and calibration, and lifts are measured in four or five systems. Noticeable differences among the rating systems is the building automation system and the commissioning criteria. Compared to others, they receive the least attention. Building Automation System (BAS) is assessed in BEAM Plus, LOTUS, and BERDE while commissioning is evaluated in BEAM Plus and GBI.

Compared to other rating systems in the analysis, BEAM Plus is the most comprehensive standard in assessing energy parameter since it includes all the criteria. GBI, LOTUS, and BERDE include eight out of the ten main criteria whereas BCA Green Mark and GRIHA addressed seven of them. The existence of the criteria reflects the emphasis of each standard for different aspects of energy.

5.3.2 Water Category

Similar to the energy category, the criteria used in water are summarized into nine headings as presented in table 7. The requirements for each criterion are demonstrated concisely.

TABLE 7. Summary of main water criteria in GBRS

Criteria	Description
Reduce Freshwater Consumption	Using water efficiently by applying efficient fixtures to reduce potable water consumption
Water Efficient Landscaping/Irrigation	Restricting the use of water for landscape irrigation purpose and preventing the depletion of ground resources
Water Metering and Leak Detection System	Monitoring activities aim to prevent water leak and save freshwater
Water Efficient Devices	Utilizing water efficient equipment to minimize unregulated water consumption
Rainwater Harvesting	Recycling grey water and harvesting rainwater helps reduce freshwater consumption
Water Quality	Ensuring the quality of potable water in the building and meet the standards
Water Consumption for cooling tower	Reducing fresh water consumption for cooling purpose
Innovative Waste Water Technologies	Using new technologies in treating wastewater to meet discharge requirements
Efficient Water use during Construction	Minimizing potable water consumption during construction phases

The interests on each water criterion by GBRS are revealed in table 8. The common emphases of all rating tools on the water category are reducing freshwater consumption and efficient water consumption for landscaping and irrigation. Other criteria are included in fewer assessment tools. Noticeably, two criteria of “Innovative Waste Water Technologies” and “Efficient Water Use during Construction” are addressed in only GRIHA rating tool.

TABLE 8. Comparison of energy criteria among six GBRS

Water criteria in GBRS	BEAM Plus	BCA Green	GBI	LOTUS	BERDE	GRIHA
Reduce Freshwater Consumption	✓	✓	✓	✓	✓	✓
Water Efficient Landscaping/Irrigation	✓	✓	✓	✓	✓	✓
Water Metering and Leak Detection System	✓	✓	✓	✓	✓	
Water Efficient Devices	✓	✓	✓	✓		
Rainwater Harvesting	✓		✓	✓		✓
Water Quality	✓				✓	✓
Water Consumption for Cooling tower	✓	✓				
Innovative Waste Water Technologies						✓
Efficient Water use during Construction						✓

BEAM Plus is still the rating tools assessing the most criteria (seven out of nine) except for “Innovative Waste Water Technologies” and “Efficient Water Use during Construction”. Following is GRIHA which addresses six criteria out of the nine main criteria. Other rating systems include four to five criteria. Compared to the energy category, the differences among the six GBRS in measuring water parameter are more significant. There are only two common grounds for the water assessment which are diminishing potable consumption and water consumption for landscaping and irrigation. In addition, there is no rating tool which covers all aspects stated in the water category.

6 DISCUSSIONS

Based on the results, the credentials given for water and energy are discussed in this chapter. The criteria which have been included in these two categories are also analysed.

As mentioned in the previous chapter, energy consumption is directly connected to environmental issues such as GHG emissions and global warming (Lu 2017). It has been studied that 40% of the total energy consumption are consumed by the building sector (Zimmerman 2012). Therefore, energy receives huge emphases in Asian building assessment tools. It accounts for the highest percentage of the total point of all analysed rating systems. Remarkably, BCA Green Mark spends 61,1% of total point for energy criteria which indicates the attempt of the Singapore government in achieving the target for energy efficiency. Singapore aims to reduce 35% of total energy consumption by 2030 (BCA 2010).

The weightages of water in GBRS are less remarkable than energy. In some rating systems, the point of the energy category is much higher than point of the water category. At present, water is addressed as a global concern because of the increasing demand for this resource (Nanda & Pring 2013). According to Satoh et al. (2017), Asian population is about 4.5 billion people which accounts for 65% of the global water supply. Water scarcity already affects to 30% of the Asian population. It is currently a major challenge for Asian countries. One of the most efficient ways to conserve water is managing water consumption in the construction industry since Rahman et al. (2019) stated that a significant volume of water is needed for construction activities and also for the manufacture of construction materials such as steel, cement and concrete. Moreover, some processes like mixing and curing concrete also require clean or potable water. Thus, it is essential to give a greater priority for water in Asian building rating tools.

Regarding energy category, it can be observed that some criteria are mentioned in all rating systems such as renewable energy, air conditioning and ventilation system, minimum energy efficiency performance, energy monitoring and control,

and lighting. These criteria refer to the crucial activities of the building and the popular strategies in energy conservation.

Currently, renewable energy is a popular approach which helps to reduce CO2 emissions and utilize available resources (Lombard et al. 2008). Therefore, it is an attractive feature in green buildings. Lombard et al. (2008) also indicated that heating, ventilation, and air conditioning system (HVAC) is the primary end use of in buildings which comprises of nearly 50% in the total building energy consumption. HVAC is an essential part of buildings providing comfort for the indoor environment. Especially, the six GBRS were developed for the tropical or subtropical countries which require a huge amount of energy for cooling devices. Thus, a good design for the ventilation system and efficient air-conditioners are addressed in all evaluation standards.

Minimum energy efficiency performance is another crucial criterion that has been emphasized in all six rating systems. Energy efficiency will reduce the total energy consumption of buildings resulting in the decrease of CO2 emission to the atmosphere. Minimum energy efficiency performance is also addressed as a prerequisite in some rating systems such as BCA Green Mark and LOTUS. Monitoring and controlling energy system are necessary to increase the energy efficiency of the building. Thus, it is also measured under the energy category. (Dang 2016.)

Besides the common interests, there are several criteria mentioned in the energy section of some systems including “Sub Metering and Calibration”, “Building Automation System”, “Lifts”, “Operation and maintenance” and “Commissioning”. The existence of each criterion in the green building rating system reveals the priority givens for that criterion.

Kumara and Waidyasekara (2013) mentioned that building automation system is an emerging technique in recent year. Building Automation System (BAS) which is also known as Building Management System (BMS) is the centralized system that controls heating, ventilation system and other electrical equipment of a building automatically (Kumara & Waidyasekara 2013). It is a useful strategy to minimize operation costs and improve the life cycle of facilities. In this study, BEAM

Plus, LOTUS, and BERDE include BAS in the energy section. It is probably because the versions of these rating tools were published after 2015 while the versions of other rating systems were implemented before 2015. As mentioned previously, the existing rating systems still need further updates in order to keep pace with the latest innovations and regulations (Shamseldin 2016). Necessary updates allow rating tools to assess building performance in a more comprehensive way and increase the efficiency of the evaluation. Since technologies and innovations develop rapidly, studies need to be conducted regularly to improve green building assessment tools. The results suggest that prospective versions of GBRS should consider building automation system as a criterion in the energy category.

In water section, there are two common criteria among the six rating systems which are freshwater consumption reduction and water use for landscaping and irrigation. Freshwater is a limited source accounting for only a trivial amount of 2,5% out of all water on the Earth. Saving this precious resource is important to ensure the supply for clean and safe potable water. Thus, “Reducing Freshwater Consumption” is mentioned in all rating tools. The amount of freshwater used for landscaping and irrigation can be tremendous because of the huge demand from plants and greenery. Therefore, it has attracted the attention of all green building assessment tools. It is possible to minimize the water consumption for these purposes, for example, by taking advantage of domestic plants which can survive without additional requirements such as water, fertilizer or pesticides (HKGBC 2016).

“Innovative Waste Water Technologies” and “Efficient Water Use during Construction” are evaluated only in GRIHA rating system. Even though innovative technology is not addressed specifically under water category in other rating tools, it is mentioned under Innovation category. However, water consumption during construction activities is rarely measured. According to Rahman et al. (2019), the amount of water used during the construction phase is remarkable. Moreover, Waidyasekara, De Silva and Rameezdeen (2012) stated that water discharged from the construction site can cause water pollution if the treatment is not handled properly. It is important to encourage alternative methodologies to minimize the use of potable water during the construction phase. Nevertheless,

data during the construction phase is still inadequate to create specific requirements for water during the construction phase (BREEAM 2011).

7 CONCLUSIONS

The aim of this study is to compare energy and water categories in Asian green building rating systems. Results from the analysis of six rating systems in Asia indicated that current building assessment tools concentrate more on energy than water. BCA Green Mark spends the most remarkable figure of 61% in the total point for energy while only 8,9% is distributed for water category. In other rating systems, the difference between the weightage of energy and water is less significant. However, water needs to receive more emphasis as it is considered as a major issue in Asia currently.

In terms of energy, the common criteria in all rating system are renewable energy, air-conditioning and ventilation system, minimum energy efficiency performance, lighting and energy monitor and control. It should be noticed that building automation system is an effective technique which is used to manage the building energy system. However, this criterion has been addressed only in BEAM Plus, LOTUS, and BERDE in the recent versions which are published after 2015. Therefore, building automation system should be also considered in the future update of green building assessment tools.

The common interests regarding buildings water management is the reduction of potable water consumption and the use of water for landscaping and irrigation. However, water consumption during the construction phase is an also important aspect that has been evaluated by only one rating tool, GRIHA. As a huge amount of water is used for construction activities, further research needs to be carried out to set up requirements for water consumption during the construction phase.

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APPENDICES

Appendix 1. Contribution of all categories into the total score of Green Building Rating Systems (%)

		BEAM Plus	BCA Green Mark	GBI	LOTUS	BERDE	GRIHA
Management		14,2			8,5	4	
Sustainable Site		13,6	22,1	10			16,3
Energy		24,1	61,1	38	26,3	16	33,7
Water		14,2	8,9	12	11,0	14	12,5
IEQ		16,0	4,2	21	11,8	10	13,5
Innovation		7,4	3,7	10	6,8		3,8
Others	Material and Waste Aspects/ Material and Resources	10,5		9			
	Materials				7,6	8	13,5
	Ecology				7,6		
	Waste & Pollution				6,8		
	Adaptation				8,5		
	Community				5,1		
	Waste Management					10	4,8
	Use of Land and Ecology					16	
	Transportation					14	
	Emissions					8	
	Building Operation & Maintenance						1,9
Total		100	100	100	100	100	100