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Sustainability assessment tool of green building renovation in Taiwan: an introduction to EEWH-RN

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The Green building evaluation system, EEWH, has been widely promulgated in Taiwan building construction since its establishment in 1999. However, the potential energy savings and sustainability improvement of existing buildings have not been explored. In response, the Taiwanese government developed a sustainable assessment tool called EEWH-RN in 2010 that focuses on Green building renovation and, in doing so, became the fourth member of the EEWH evaluation n family. While introducing two evaluation methods of EEWH-RN (i.e. the EEWH performance method and carbon reduction method), this study assesses the improved EEWH performance and carbon reduction ratios, based on examples of the Green Building Renovation Plan funded by the Taiwanese government. In addition to providing a valuable reference for devising a preliminary EEWH-RN rating standard, results of this study significantly contribute to future policy making decisions for Green buildings renovation in Taiwan.

Introduction

Among the numerous building sustainability assessment tools developed in the last two decades include BREEAM, LEED, SBTool, CASBEE, and Green Star. Taiwan's Green building evaluation system, EEWH, became the fourth building sustainability assessment tool worldwide in 1999, behind BREEAM, LEED and GBTool, and the first system developed specifically for tropical and subtropical climates. Taiwan demonstrated its determination in promoting green building by mandating that all new public buildings with total construction costs exceeding $US 1.67 million obtain EEWH Green Building Candidate certification before receiving a construction permit. Upon completion of building construction, Green Building Label certifications must also be acquired for building use license. Until now, the EEWH evaluation system was applied to 3164 Green Building Candidate and Green Building Label certifications in Taiwan.

Despite the success of above legislative efforts in regulating the sustainable quality of new buildings in Taiwan, permit applications for new construction projects have gradually reduced annually owing to highly developed land-use. Statistics indicate that newly constructed buildings reduced to just 3% of the total building stock during 1990 to 2008, while existing buildings represented 97%. The lack of sustainability design concepts in existing buildings often leads to inferior green building performance and wasted energy consumption. A research program was subsequently initiated to devise a Green Building evaluation tool specific for building renovation. Following a survey of worldwide sustainability assessment tools for existing building and previous experiences of Taiwan's Green Building Renovation Plan, the fourth member of the EEWH evaluation family, EEWH-RN (Renovation), was officially launched in 2010.

Background of Sustainability Assessment tools for existing building

This study investigated three major sustainability assessment tools developed specifically for existing buildings (i.e. BREEAM, LEED and CASBEE).

BRE Environmental Assessment Method (BREEAM) of the United Kingdom is an environmental assessment tool for use in the design, construction, and refurbishment stages of a broad range of building types. Schemes focusing on existing buildings include BREEAM In-Use and BREEAM Refurbishment (Domestic & Non-domestic). BREEAM In-Use was developed to encourage better building management and to reduce energy consumption in existing building, while BREEAM Refurbishment is scheduled for completion in early 2012.

LEED developed in the United States is one of the most recognized assessment tools globally. Eight building-oriented assessment schemes are currently available. The LEED for Existing Buildings (LEED-EB) was established to evaluate the operating efficiency of existing buildings, as well as their environmental impact and maintenance. The energy performance must be based on metered energy consumption of 12 continuous months.

In Japan, the core concept of CASBEE assessment is building environmental efficiency (BEE). CASBEE-EB (Existing Building) targets existing building stock, based on operation records for at least one year and measurement value of indoor environment quality after completion. Also, CASBEE-RN (Renovation) attempts to determine the degree of increased building environmental efficiency (ΔBEE) or energy saving (ΔBEE_{ES}) before and after renovation.

Most policies and certifications of building sustainability assessment tools worldwide focus on newly constructed buildings. However, according to related studies, the fact that current legislative efforts are insufficient to achieve national environmental or carbon reduction targets (Radhi, 2009), demonstrates the necessity of voluntary initiatives such as building renovation, equipment system retrofit or building energy management. Although the above mentioned building sustainability assessment tools differ in categories, score systems, and assessment schemes (see Table 1), environmental impact and energy use are of priority concern. However, older buildings find it extremely difficult to achieve EB certification, while the EB standard is nearly the same or slightly lower than the new construction (NC) standard. For instance, despite the promulgation of LEED-EB and CASBEE-EB since 2004, relatively few certified buildings exist in comparison with the success of the NC scheme (Ciochetti & McGowan, 2010).

Table 1. Characteristic of Building sustainability assessment tools for existing building.

BAS Tools	Country	Categories and Weightings	Scoring system	Rating
BREEM In-Use	UK (2009)	Energy (26.5%) Water (8%) Materials (8.5%) Waste (5%) Heath & Wellbeing (17%) Pollution (14%) Transport (11.5%) Land use & Ecology (9.5%)	The points each category is attain in weighted according to the perceived importance of their environmental impact	Pass Good Very Good Excellent Outstanding
LEED-EB	USA (2004)	Sustainable sites (26) Water efficiency (14) Energy & Atmosphere (35) Materials & resources (10) Indoor environmental quality (15) Innovation (6) Regional priority (4)	The allocation of points between credits is given based on the environmental impact of each category	Certified Silver Gold Platinum
CASBEE-EB	Japan	Q1.Indoor environment Q2.Quality of service Q3.Outdoor environment on site L1.Energy L2.Resources & Materials L3.Off-site environment	1-5 score levels apply to concerned items in each category (Q: Quality of building; L: Environmental load; BEE: Q/L)	Poor Fairy poor Good Very Good Excellent

Green Building evaluation family in Taiwan

The development of EEWH evaluation family involved collaboration between scholars, research institutions, companies and organizations under research programs were funded by the Architecture and Building Research Institute (ABRI) of Taiwan. EEWH evaluation systems are categorized according to ecology, energy saving, waste reduction, and health (EEWH). Each category has weighted and accumulative indicators with different scoring ranges, totaling 100 maximum points (continuous and including decimal points), and graded on five rating levels: Diamond, Gold, Silver, Bronze and Qualified. By using progressive formulas in each indicator, the EEWH scoring system differ from the point system of

BREEAM and LEED, thus avoiding drawbacks such as an overemphasis on simplified quantifications and priority consideration over easy yet non-environmental related factors (Humbert et al., 2007).

Enacted in1999, the first edition of EEWH Green Building evaluation system is extensively adopted for newly constructed buildings. However, applying a single evaluation system for various building types is clearly insufficient and fails to develop the full potential of green building evaluation systems. ABRI subsequently amended the original Green Building evaluation system and named it EEWH-BC (Basic Version). Accompanied by four specific evaluation systems, EEWH-RS (Residential), EEWH-GF (Green Factory), EEWH-RN (Renovation) and EEWH-EC (Ecological Community), a complete EEWH evaluation family was formed in 2011. EEWH-BC, EEWH-RS and EEWH-GF are applied to new and existing building (see Table 2), while EEWH-RN evaluates the improved green building performance and energy efficiency before and after renovation.

Table 2. Indicators and applicable schemes for EEWH-BC, EEWH-RS and EEWH-GF.

System	Categories	Indicators		Schemes
EEWH-BC (2011)	Ecological	Biodiversity Greenery On-site Water Retention		New or existing buildings not covered in EEWH-RS and GF (Total score: 100)
	Energy Savings	Daily Energy Savings	Building envelope AC systems Lighting systems	
	Waste Reduction	CO_2 Reduction Construction Waste Reduction		
	Health	Indoor Environment Water Resource Sewage & Garbage Improvement		
EEWH-RS (2011)	Ecological	Biodiversity Greenery On-site Water Retention		New or existing residential buildings served for long or short term accommodation (Total score: 100)
	Energy Savings	Daily Energy Savings	Building envelope U value of exterior wall U value of windows AC systems Lighting systems Fix equipment	
	Waste Reduction	CO_2 Reduction Construction Waste Reduction		
	Health	Indoor Environment Water Resource Sewage & Garbage Improvement		
EEWH-GF (2010)	Required	Executives Promise Equipment TAB verification		New or existing factories with primarily indoor operations (Total score: 100)
	Ecological	Greenery On-site Water Retention		
	Energy Savings	Daily Energy Savings	Building envelope AC systems Lighting systems (Energy cost method)* Green transportation Renewable energy	
	Waste Reduction	CO_2 Reduction Construction Waste Reduction Daily Water Saving Sewage & Garbage Improvement		
	Health	Indoor air quality controls Indoor Acoustic environment Indoor Lighting environment Indoor Ventilation Interior Building Materials (Low-VOC) Recreation and Health Management		

*An optional energy cost simulation by software such as DOE-2, e-QUEST, Energy plus…etc

Considerations in the tool development process

Green Building renovation plan of Taiwan

This study examined Taiwan's previous experiences of building retrofitting. Between 2002 and 2011, the Taiwanese government invested $US 56.7 million in a program aimed at renewing existing buildings, called the Green building renovation plan (GBRP). In the recent decade, 468 government buildings and national universities were renovated as model projects for green building renovation. Only one or two improvement measures were normally adopted owing to financial and technical constraints. Equipment system retrofitting is the most frequently adopted improvement measure, followed by building envelope/shading improvement and on-site water retention improvement (see Table 3). Indoor environment improvement and utilization of renewable energy are less frequently adopted because of related technical difficulties, higher equipment prices, and lack of public awareness. Equipment retrofit measures applied to existing buildings include high performance AC systems, energy-saving lighting systems, heat pump systems, and energy management. Investment costs for equipment system retrofit are around $US 100,000, while other improvement measures of GBRP cost $US 134,000.

Table 3. Adopted frequency of improvement measures for Green Building Renovation Plan

Adopted measures in one case	Amount of cases	Improvement measures adopted in GBRP	Adopted frequency (times)
One measure	293	Equipment system retrofit	426
Two measures	129	Building envelope/opening shading	82
Three measures	28	On-site water retention	63
Four measures	13	On-site greenery/roof garden	56
Five measures	1	Utilization of water-saving systems	52
Six measures	3	Indoor environment improvement	20
Seven measures	1	Renewable energy utilization	18

Basic considerations of Taiwan's EEWH-RN

Conventional assessment tools incorporate two applicable schemes for existing building: a) operating efficiency and environmental sustainability (EB) and b) improved performance after renovation (RN). For most existing buildings in Taiwan, the EB standard is difficult to achieve without significant retrofitting costs and efforts. Owing to widely anticipated applications, EEWH-RN is assumed to be flexible, quantifiable, achievable, and structure under the existing EEWH Green Building evaluation systems (e.g. EEWH-BC, RS and GF). Considering the experiences of implementing GBRP, the potential energy savings and carbon reduction are equally important as improving green building performance. Moreover, financial and technical difficulties in the renovation process explain why the rating standard of EEWH-RN should not be too high in order to encourage voluntary green building renovation.

Evaluation methods of EEWH-RN

EEWH renovation performance and carbon reduction performance are two methods to evaluate the EEWH-RN system. The former evaluates the overall improved green building performance based on the scores of EEWH systems, while the latter focuses on improving equipment systems, resulting in carbon reduction and energy savings during operations. Applicants can choose the most favorable or most easily implemented methods for evaluation.

EEWH renovation performance method

New or existing buildings can apply for EEWH-BC, EEWH-RS and EEWH-GF certification if compliant with requirements. EEWH performance represents the scores under its 100 maximum points system. For renovated building, EEWH renovation performance represents the improved ratio of EEWH performance scores (ΔRSr) under the same criteria as EEWH-BC, EEWH-RS and EEWH-GF, where the maximum improvement potential RSc (RSmax - Rsb) as the denominator and the improved EEWH performance scores ΔRS (Rsa - Rsb) as the numerator. The EEWH renovation performance (ΔRSr) is determined using Eq.1.

$$\Delta RSr = \left(\frac{RSa - RSb}{RSmax - RSb} \right) \times 100\% \quad (1)$$

Where Rsb = EEWH performance scores before renovation; RSa = EEWH performance scores after renovation; and RSmax (maximum achievable scores) = maximum scores determined based on previous certified buildings, 70 points for BC and RS; and EEWH-GF with a central AC systems and a non-central AC systems have 83 points and 73 points, respectively.

Carbon reduction performance method

The carbon reduction performance method focuses on improving the efficiency of equipment systems such as AC systems, lighting systems, and heating systems, as well as incorporating renewable energy use. However, equipment systems vary in energy source requirements (e.g., electricity, fuel, and gas), explaining why the corresponding energy use must be converted into equivalent CO_2 emissions before and after renovation while, simultaneously, calculating the annual carbon reduction ratios (ΔCRr). Here, the carbon reduction performance is determined using Eq.2, where the annual carbon emissions before renovation (CEb) is assumed to be the denominator and the reduced annual carbon emissions ΔCR (CEb - CEa) is assumed to be as the numerator.

$$\Delta \mathrm{CRr} = \left(\frac{\mathrm{CEb} - \mathrm{CEa}}{\mathrm{CEb}} \right) \times 100\% \tag{2}$$

Where CEb = the annual carbon emissions before renovation (kg-CO_2/yr), and CEa= the annual carbon emissions after renovation (kg-CO_2/yr).

Equipment renovation involves a central AC systems, the annual energy consumption can be calculated by simulation software such as DOE-2, e-QUEST, or Energy plus. For a lighting systems, non-central AC systems renovation or renewable energy utilization, the reduced annual carbon emissions (ΔCR) can be determined using simplified calculations such as improved equipment efficiency multiplied by annual operating hours. All central AC systems renovation must be verified by testing, adjusting, and balancing (TAB) to ensure that systems are functionally tested and operated.

EEWH-RN rating scores

EEWH-RN uses the same five rating levels as the other EEWH systems do. The improved ratio (%) of the EEWH renovation performance and carbon reduction performance are rated as Qualified (5%≦ΔRSr or ΔCRr＜10%), Bronze (10%≦ΔRSr or ΔCRr＜14%), Silver (14%≦ΔRSr or ΔCRr＜17%), Gold (17%≦ΔRSr or ΔCRr＜20%) and Diamond (20%≦ΔRSr or ΔCRr).

Applicability and calibration of rating system

This study tests and calibrates the EEWH-RN rating system by selecting a renovated wine storage warehouse as a case study for the EEWH renovation performance method. Before renovation, the building condition was very poor, as evidenced by problems such as insufficient greenery and on-site water retention, unfit insulation and poor indoor environment, and inefficient water appliances. In 2005, as a demonstrated project of GBRP, this building received funding of over $ US 1.06 million for renovation into a government office. Following the adoption of various improvement measures, the improved ratio of EEWH performance scores (ΔRSr) is 58.63% under the EEWH-BC criteria (see Table 4), which qualifies for Diamond certification of EEWH-RN (Lin et al., 2010). However, for most renovated buildings that could only afford to adopt one or two improvement measures in GBRP, the expected ΔRSr is about 7.3 ~ 13.6%, which is Qualified or Bronze certification.

Table 4. Improvement measures and scores of renovated wine storage warehouse

Indicator	Improvement measures	RSa	RSb
Biodiversity	Site is smaller than one hectare hence exempted from evaluation	-	-
Greenery	Increase on-site greenery and adopt roof garden with shrubs and vines	0.00	3.29
On-site Water Retention	Increase permeable paving, roof garden soil and rainwater retention pond	0.00	2.18
Daily Energy Savings-Building envelope	improve roof/wall insulation and install horizontal/vertical shading for openings	3.00	4.47
AC systems	Install high efficiency chiller/air-to-air heat exchanger/CO_2 sensors/nature ventilation tower	3.00	4.63
Lighting systems	Install daylight guide plates/task-ambient lighting systems/high efficiency lamps & ballasts	3.00	5.17

Table 4. Improvement measures and scores of renovated wine storage warehouse (continued)

CO_2 Reduction	Old building structure conservation/light partition/durability pipe design	1.50	8.00
Construction Waste Reduction	Balance of excavation earth/air pollution control during renovation	0.70	3.29
Indoor Environment	Improve indoor acoustic/lighting/ventilation environment and adopt green materials	0.00	3.68
Water Resource	Install saving toilets, urinals, taps and rainwater recycling system	1.50	6.50
Sewage & Garbage Improvement	Install sewage/garbage facilities and recycling receptacles	1.50	2.01
Total scores		14.20	43.22
RSmax =	70-6.3=63.7(6.3 corresponding points was deducted from RSmax when exempted from the Biodiversity indicator)		
RSc=RSmax-ΣRSb=	63.7-14.2= 49.5		
ΔRSr=ΔRS/RSc=	29.02/49.5=58.63%		

Figure 1. Wine storage warehouse before and after renovation.

In a case study of the carbon reduction performance method, this study calculates the potential annual energy savings of 16 interior lighting systems retrofitting projects in 2009, and 12 AC systems retrofitting projects in 2010 associated with GBRP. In Taiwan, the AC systems and lighting systems consume almost 45% and 35% of total energy use, respectively. Reducing AC systems and lighting systems energy consumption are thus highly promising means of reducing carbon emissions during operations, as well as the easiest means of construction. The main measures for GBRP AC systems retrofit include testing, adjusting, and balancing (TAB); install building energy manager system (BEMS); replace over-designed chiller with smaller capacity one; install frequency conversion to original systems, so as to become variable water volume(VWV) and variable air volume(VAV) systems; utilize CO_2 concentration control and pre-cooling air systems.

A previous study demonstrated that AC systems retrofit can reduce total energy use by 11.75%(Chang et al., 2012.); meanwhile, replacing T8 fluorescent lamps with T5 fluorescent lamps and LED indicator lights can achieve a 10-17.5% reduction in energy consumption for existing buildings (Chang & Lin, 2011.). Because all retrofitting projects use only electricity for energy source, the annual carbon reduction ratios (ΔCRr) of AC systems and lighting systems retrofitting appear to be around 10%, which roughly qualifies for Bronze certification of EEWH-RN.

As for above mentioned considerations of EEWH-RN, that the rating standard should not be too high for most GBRP projects. Both case study results of the EEWH renovation performance method and carbon reduction performance method demonstrate that the current rating system for EEWH-RN is practical, achievable and conducive to the experiences of green building renovation in Taiwan.

Conclusions

Given growing public awareness of global sustainability, improving the green building and energy performance of existing buildings is undoubtedly of priority concern in developing building sustainability assessment tools. However, mandating that existing buildings with inferior sustainability performance achieve the same standard as newly constructed buildings is impractical without a large amount of money and effort invested. For most common buildings, the desired evaluation standard appears to be the degree of increased performance after renovation. To facilitate a voluntary upgrade of sustainability performance and efficient energy performance for existing buildings, the Taiwanese government devised a sustainability assessment tool EEWH-RN, based on the structure of EEWH Green Building evaluation systems (e.g., EEWH-BC, RS and GF). In addition to the EEWH renovation performance, the carbon reduction performance is also an alternative method for EEWH-RN evaluation.

In summary, EEWH-RN provides two generalized approaches for dealing with sustainable renovation and improving the efficiency of equipment systems. However, even with considerable effort and money, the improved performance is limited due to financial and technical difficulties in renovation projects. Owing to widely anticipated applications, the rating system of EEWH-RN is calibrated in this study and demonstrated to be an achievable standard. Meanwhile, regulation policies aimed at the design and construction of new buildings should maintain a high standard to fully optimize the potential sustainability in all building stages.

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