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Baseline and Water Efficiency for Green Building in Taiwan

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ABSTRACT

More than a thousand buildings have been certified as green buildings using this evaluation system since 1999 when the green building evaluation system of Taiwan was first applied. It provides policy makers as a form of positive feedback from the quantitative effects of water conservation efforts. The present study offers a calculation process for estimating the quantitative volume of water saved by practical green buildings. The baseline water usage for all kinds of buildings was determined to serve as the criterion for determining the water saving efficiency of individual buildings. An investigation of the average water saving rate from 2000-2013 for 1,320 buildings certified as green buildings was conducted to validate the estimation results. This research used 568 cases of green buildings which involved the rainwater harvesting system design and operation to be the validation as well. The evaluation result shows average 48% water saving rate in these cases involved rainwater harvesting system. Water savings will inevitably follow from the use of water-saving appliances or water-saving designs for buildings. The investigation on the difference between the actual water consumption of the building awarded with green building certification and the general building had been verified. Through the field survey, the water efficiency from rain water harvesting operation was evaluated and confirmed. It is proved the significant contribution to water efficiency from adoption of saving water design and rainwater reuse system in green buildings.

Keywords: *design process, green rating tool, high-performance building*

1. INTRODUCTION

The green building evaluation system used in Taiwan was first applied in 1999 and initially utilized a building's water efficiency as the threshold index for determining the building's environmental impact. More than a thousand buildings have been certified as green buildings using this evaluation system since then. It provides policy makers as a form of positive feedback from the quantitative effects of water conservation efforts. Theoretically, water-saving designs and the adoption of water-saving facilities should benefit buildings in terms of their water usage efficiency . However, actual real-world water usage is complex, being affected by a wide range of human behaviors and other factors .Regarding the issue of the effective use of water resources, the actual water consumption of a building with a green building certification should be different from those of buildings without water-saving designs. Relatedly, the question of whether substantial water-saving effects are achieved by such designs, as well as questions regarding their energy-saving and carbon-reduction benefits, are widely discussed. Therefore, it is requested with various investigations had to be undertaken to answer them.

To date, however, there are still no solid means of verifying or providing clear evidence to determine the quantitative effects of various water conservation strategies. A model for estimating water-saving benefits in order to clarify the effective use of water resources was established in previous research. To that end, an empirical investigation of buildings with green building certification was conducted to verify the values estimated by the model after statistical analysis. More specifically, quantified values of reasonable water-saving benefits for Taiwan for every year were derived to examine the effects of water conservation and to validate the proposed model. In this study the actual cases awarded by green building certification since 2000 to 2013 are taken as the research subjects [9]. This study would focus on the water conservation measures for green buildings in Taiwan with the aim of providing a quantitative procedure for proving water-saving efficiency.

2. WATER INDEXES AND EVALUATION

The water conservation index is a ranking system for the adoption of water-conserving items, including water closets, urinals, faucets and baths, and for the reuse of rainwater and grey water. As a practical process of the assessment of the water index of a green building's water resource indicator system WI value, the applied building should submit the proof documents about the saving water design items; then, the referee committee would confirm and determine the final rating value of the WI index. This rating system focuses on the saving water design and the adoption of water efficiency facilities for green buildings. The evaluation consideration engages the design and facility, not including usage patterns or behavior styles. Therefore, the rating value of saving water is a conceptual assessment for the water efficiency parameter without real water saving volume.

To more precisely estimate the quantity of water actually consumed by a given green building, the factor of operating time was added to the building categories when estimating the baseline for the quantity of water consumed. After the water consumption per unit of the floor area of a building with green building certification was acquired, this study used statistical quantitative methods and an empirical investigation for comparison and analysis, determining the actual gross water consumption as a basis for estimating the quantity of a building's annual water conservation. Accordingly, the baseline for annual water consumption for each category of building Wty (m^3/year) was established, and the formula for the estimated quantity of annual water conservation Wst (m^3/year) is provided as Equations 1–4.

$$W_{ty} = A_f \times WUI$$

Equation 1

$$W_{st} = W_{ty} \times (WI \div 9)$$

Equation 2

$$R_{sw} = W_{st} \div W_{ty} \times 100\%$$

Equation 3

$$R_{rs} = W_{rs} \div W_{ty} \times 100\%$$

Equation 4

W_{ty}: Annual water consumption for each category of building (m^3/year).

A_f: The floor area of a building (m^2).

WUI: Water consumption density per unit area of a building ($m^3/m^2 \cdot$year).

WI: Water index of a green building's water resource indicator system ($0.0 \leq WI \leq 9.0$).

W_{st}: Annual water saving of building (m^3/year).

W_{ty}: Annual water consumption of each category of building (m^3/year).

R_{sw}: Annual water saving rate of building (%).

R_{rs}: Annual rainwater substitution rate of building (%).

The score for the water resource indicator system for a green building's rating assessment system, WI, is the key parameter for estimation. This study used the real cases with green building certification, and each case has a certified rating value of the WI index. The average values of the water resource indicator rating scores for 2007–2013 (WI) were, for the most part, normally distributed between 3.0 and 5.0. According to the survey green building certificated cases, the annual water saving rate Rsw and rainwater substitution rate Rrs would be estimated.

3. BUILDING CATEGORY AND WATER USAGE BASELINE

The water demand and the actual water consumption of buildings are actually quite complex, not only because of the difference in building types, but also because even among buildings of the same type, individual buildings may differ substantially due to factors, such as building age, occupancy, density, etc. Moreover, a building's usage and demand patterns will change after the actual construction is completed. All of these factors cause considerable difficulty in accurately estimating water consumption. Therefore, in order to more accurately estimate the actual consumption of green buildings to serve as the basis for assessing water-saving efficiency, the operating time factor was added to the factor of building types as one of the water consumption estimation criteria [10]. Herein, the water unit intensity (WUI) formula is defined by the parameters of occupancy density, yearly water usage and occupancy rate, shown as Equations (5)–(8).

$$WUI = P_{di} \times Q_{wi} \times F_{ri}$$

Equation 5

$$P_{di} = \prod_{i=1}^{12} P_{di}\ ;\ 0.03 \le P_{di} \le 1.2$$

Equation 6

$$Q_{wi} = \prod_{i=1}^{8} Q_{wi}\ ;\ 1 \le Q_{wi} \le 130$$

Equation 7

$$F_{ri} = \prod_{i=1}^{5} F_{ri}\ ;\ 0.4 \le F_{ri} \le 0.8$$

Equation 8

WUI: Water consumption density per unit area of the building ($m^3/m^2 \cdot$year).

P_{di}: Person density (person/m^2).

Q_{wi}: Yearly water usage (m^3/person/year).

F_{ri}: Occupancy rate (%).

This study proposes WUI as the definition of building water usage density and to serve as the baseline of building water usage to evaluate the water efficiency of building water consumption. Due to the various categories of buildings, this study, in accordance with existing literature and relevant research and investigations, divided the buildings according to 52 different types of water utilization based on the building's utilization time characteristics in order to estimate the baseline for water consumption more precisely. After estimating the parameter levels for the standardized building water consumption and water consumption parameters, the baseline for each type of water consumption was estimated.

Overall, other than accommodation or medical buildings, which involve everyday-life water demands, the per-capita water demand per unit of buildings in general is mainly determined by the use of toilets and for cleaning activities. The water demands of accommodation buildings, on the other hand, include the water needed for cleaning and bathing, toilet flushing, cooking and other purposes. Based on the unity and efficiency principle of the estimation formula and for the sake of consistency in our assessments, water consumption was translated into average per-capita water consumption per unit for all building types. A building's total water consumption is mainly influenced by the two factors of per-capita consumption per unit and user density, and basically, these two factors are independent variables. With regard to the building category, spatial contrasts were computed by referring to 52 types of space according to building categories A–I under the building code of Taiwan.

4. INVESTIGATION AND VALIDATION

In this study the actual cases awarded by green building certification since 2000 to 2013 are taken as the research subjects with totally 1224 cases, the rainwater harvesting system is the focus of this research. Through the field survey, the water efficiency from rain water harvesting operation of 568 cases was evaluated and confirmed which involved the rainwater harvesting system design and operation to be the validation. The adoption rate of rainwater harvesting system design and operation in green building certificated cases is around 50% in general since 2000 to 2013, as shown in Figure 1.

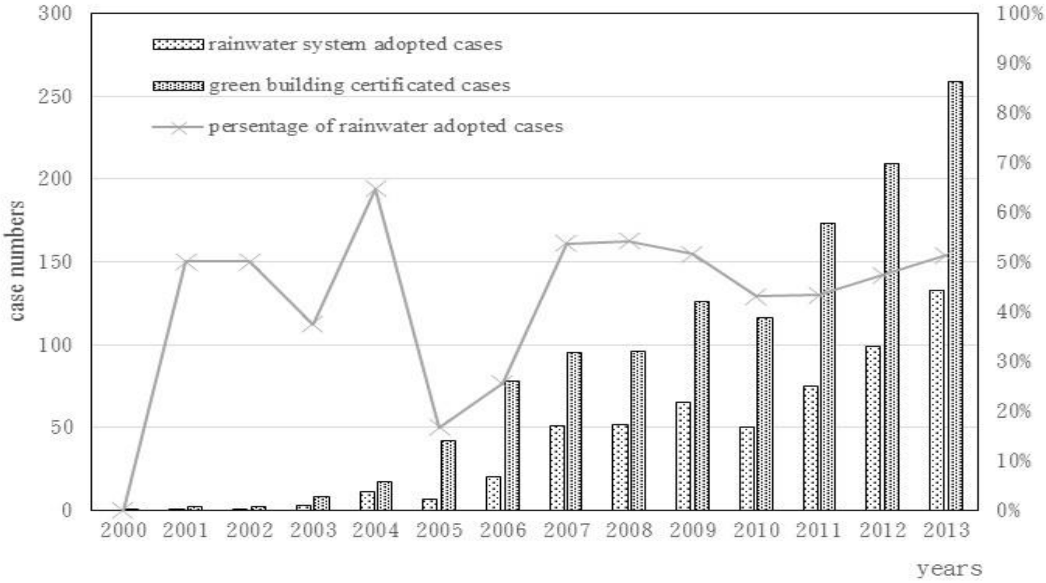

Figure 1: Green building certificated cases with rainwater system design

It is not possible to survey all green building certified cased with water consumption data. Thus, limited real cases of green building certification with confirmed data were selected to validate the efficiency of rainwater system. Due to the water quality standard and utility needs, the water saving rate was limited under 60% in evaluation system. Meanwhile, the rainwater substitution rate has maxima for different building type and utility needs. Herein, three groups of building types were defined from the 52 categories as residential, commercial and productive usage.

The residential use is daily usage for life including drinking, bathing, washing and etc.. The commercial use is daily usage for working area mostly is for toilet, washing, cleaning and etc.. The productive use is the usage for production area and the utility is vary and comprehensive including factory, restaurant, sport center, hospital and etc.. The usage includes producing process, toilet, washing, cleaning and etc.. Therefore, each category has maxima rainwater substitution rate for calculation from 20% to 55%. According to the reasonable limitation of maxima substitution rate, the green building certificated cases could be evaluated from water saving rate to rainwater substitution rate which the contribution framework of rainwater system adoption could be identified and recognized.

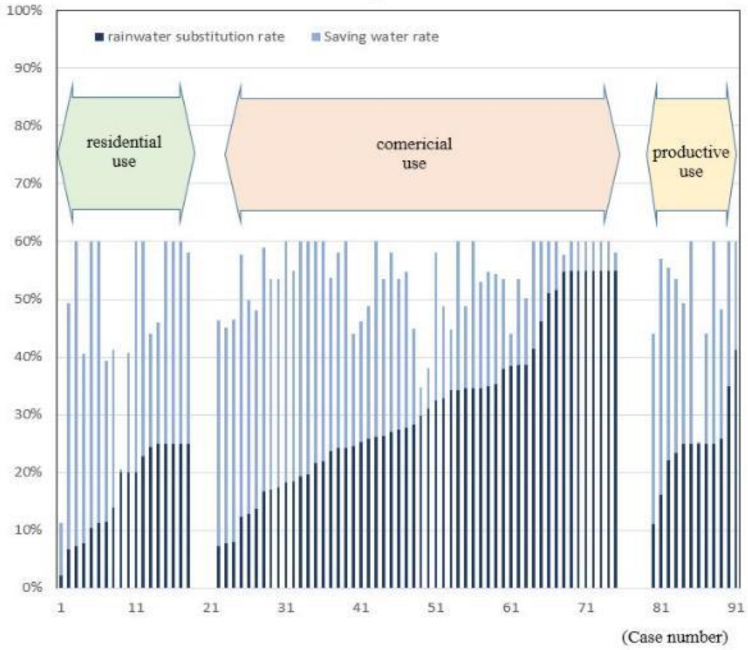

Figure 2: Distribution of rainwater substitution rate and water saving rate

This study used 91 cases of green buildings which involved the rainwater harvesting system design and operation to be the validation. Figure 2 shows the distribution of rainwater substitution rate and water saving rate of three group's buildings. It reveals that the rainwater substitution rate of residential use has lower rate of average 17%. As a result, the evaluation result shows average 54% water saving rate in these cases involved rainwater harvesting system. Initially, the average rainwater substitution rate is 28% as shown as Figure 3.

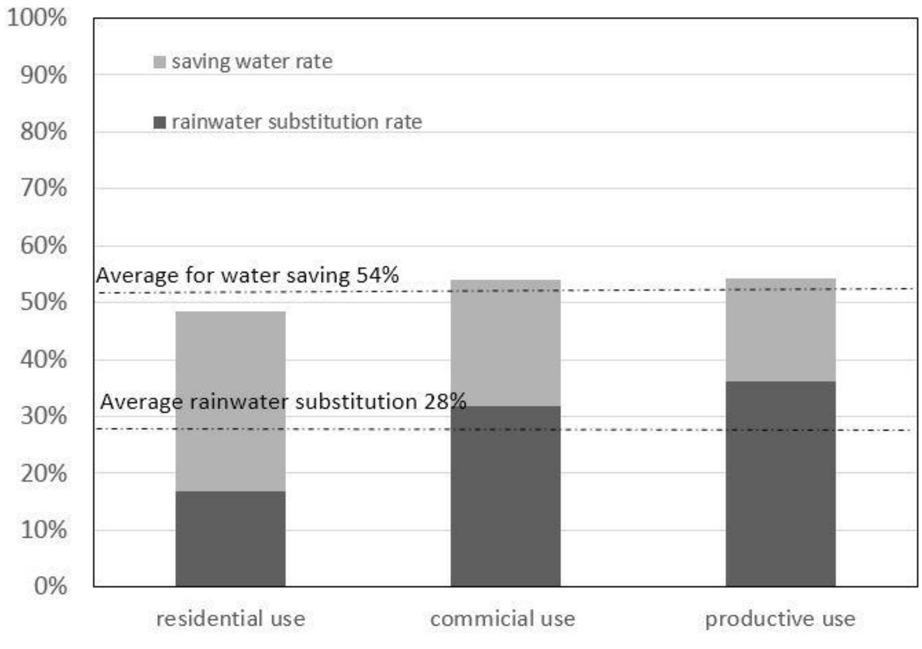

Figure 3: Comparison of rainwater substitution rate of three group's buildings

5. CONCLUSION

In this study the real cases awarded by green building certification since 2000 to 2013 are taken as the research subjects. WUI is proposed as the definition of building water usage density and to serve as the baseline of building water usage to evaluate the water efficiency of building water consumption. This conception is used to evaluate the water conservation in green building as the index to improve the water efficiency. The results are adopted by carbon footprint calculation model and link to low carbon evaluation system in Taiwan. Through the field survey, the water efficiency was evaluated and confirmed. This research used 91 cases of green buildings which involved the rainwater harvesting system design and operation to be the validation. The evaluation result shows average

54% water saving rate in these cases involved rainwater harvesting system. Initially, the average rainwater substitution rate is 28%. It is proved the significant contribution to water efficiency from adoption of water saving design and rainwater reuse system in green buildings.

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