

Advanced Electricity Use Efficiency Benchmarks for Governmental Office Buildings in Taiwan [†]

Kuo-Tsang Huang ¹, Pei-Lun Fang ^{1,*} and Hung-Peng Chang ²

¹ Department of Bioenvironmental Systems Engineering, National Taiwan University, Taipei 10617, Taiwan

² Foundation of Taiwan Industry Service, Taipei 10617, Taiwan

* Correspondence: fangloon1221@gmail.com

[†] Presented at the 7th International Conference on Architecture, Construction, Environment and Hydraulics 2025 (ICACEH 2025), Kaohsiung, Taiwan, 5–7 December 2025.

Abstract

A framework was developed in this study for setting and adjusting energy-saving targets for existing public-sector office buildings. Using self-reported energy data, we removed outliers and grouped buildings by average daily operating hours. We analyzed electricity use intensity distributions and assigned reduction rates based on each building's percentile within its group, allowing for larger improvements from high-consumption buildings while limiting pressure on already efficient ones. The framework achieved an average annual energy-saving effect of about 1% and can inform future revisions of energy management policies and target values for public office buildings.

Keywords: energy use intensity; energy efficiency improvement; energy conservation in office buildings; EUI

1. Introduction

The building industry accounts for a substantial proportion of global energy consumption and greenhouse gas emissions, positioning it as a critical element for achieving long-term net-zero emissions targets. Improving building energy efficiency has become a core direction for energy transition policy in various countries [1]. In promoting energy-saving policies, public-sector office buildings are often viewed as a policy demonstration and a pioneer in driving improvements in the private sector; thus, setting reasonable and feasible targets is crucial.

Among building energy performance indicators, energy use intensity (EUI) is frequently adopted. EUI standardizes energy consumption across buildings of different scales and purposes, serving as a foundation for developing energy-saving goals and policies, and has been explored through various studies and target-setting methods [2,3]. Chung et al. established EUI percentile tables for commercial buildings in Hong Kong by developing a benchmarking model that considers all significant explanatory variables affecting energy consumption, providing a basis for owners and policymakers to initially judge a building's relative energy performance [4]. Recently, researchers have also proposed composite building energy performance indices or benchmark reference values that incorporate various building influencing factors to improve the applicability of the EUI value to different building types [5].

However, existing methods provide one or a few groups of EUI benchmarks for different types of building or estimate a reasonable EUI range and then hope units to strive



Academic Editors: Teen-Hang Meen,
Chern-Hwa Chen and
Cheng-Fu Yang

Published: 12 May 2026

Copyright: © 2026 by the authors.
Licensee MDPI, Basel, Switzerland.
This article is an open access article
distributed under the terms and
conditions of the [Creative Commons
Attribution \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) license.

for energy savings. Therefore, we developed an easily understandable, reasonable, and adjustable annual energy-saving target allocation framework for existing public-sector office buildings in Taiwan. This framework is consistent with the goals of energy-saving policies, tailoring energy-saving targets to the building's current energy consumption status, and serving as a reference tool for future revisions of energy management and EUI benchmarks for public office buildings.

2. Methods

2.1. Building EUI

We used EUI as the core evaluation indicator for building energy consumption. The origin of EUI can be traced back to the Commercial Buildings Energy Consumption Survey promoted and conducted by the United States Department of Energy in the 1980s, where EUI was established as the metric for the survey and analysis. EUI is used to standardize building energy consumption and quantify the energy consumed per unit of floor area within a specific time. Therefore, EUI can be applied to buildings of different locations, uses, and sizes, converting them into a standardized numerical value for fair and meaningful comparison. EUI has been widely used in academic research, primarily to analyze the effects of energy-saving implementations such as building passive design and operational optimization, and plays a vital role in formulating energy-saving strategies, policies, or setting energy standards [6].

In this study, EUI was used to explore the annual electricity consumption per unit of floor area, with the unit being kWh/m² year. The calculation method is shown in Equation (1), utilizing this simple and clear energy consumption measure to establish a basis for optimizing energy efficiency and as a rational indicator for policy promotion.

$$EUI = \frac{E_{Annual}}{TFA} \quad (1)$$

Here, E_{Annual} represents the unit's total annual electricity consumption (kWh), and TFA is the building's total floor area (m²).

2.2. Data Source and Analysis

The data source for this study is the Government Agencies and Schools Energy Conservation Reporting System established by the Energy Administration, Ministry of Economic Affairs, R.O.C., Taiwan [7]. This database includes years of annual energy use and basic building information from government agencies and schools at all levels, providing a large and detailed collection of data.

We chose existing buildings from before the year 2023 and used 2023 reported data as the baseline, focusing on office-type buildings. To maintain data quality, screening criteria were established. By comparing multi-year reported data, poor quality data, such as missing values, zero values, or duplicate entries, were eliminated. Then, buildings with stable electricity consumption and fixed floor area were selected. After initial screening, a simple statistical distribution analysis was performed to exclude obvious outliers, and outliers in per-unit-area electricity consumption were removed to minimize the impact of reporting errors on the analysis results. After screening, a total of 1596 valid data records remained.

To facilitate subsequent statistical analysis and comparison, we considered the influence of different operating times on building energy consumption patterns. To mitigate the interference of varying operating hours on comparison results, average daily operating hours was adopted as the primary and straightforward method for grouping. Three of the most common and representative average daily operating hours 8, 10, and 24 h were set for

typical office uses. Table 1 shows the detailed number of data records and types of units for each group. We focused on the reasonable energy-saving potential and responsibility that each agency should achieve under the same operating pattern, rather than directly judging the superiority or inferiority of EUI between different buildings. Therefore, although differences in building age, equipment type, and location climate affect EUI performance, they are treated as the existing conditions of each agency in this study's analysis and were not further eliminated or adjusted.

Table 1. Agency types grouped by average daily operating hours.

Average Daily Operating Hours (Hours)	Data Quantity	Unit Type
8	1051	General local household registration offices, district offices
10	311	Central administrative agencies, county/city governments
24	234	Police agencies, fire departments

2.3. Setting Energy-Saving Targets

Traditionally, energy-saving policies group buildings by their EUI distribution and set the group median as the target threshold. To simplify grouping and ensure that the burden on operating units remains reasonable, we adopted target setting based on each building's historical EUI. Buildings were first grouped by similar operating hours, and their percentile rank within the group was used to evaluate EUI performance. Different annual saving ratios were then assigned according to this rank, giving each building a tailored and reasonable target EUI. This method promotes energy-saving policies while accounting for each building's inherent potential and responsibility.

Based on the data within the three operating hour groups, a percentile index Q_i between 0 and 1 was defined for each building according to its annual EUI. Q_i was used as a standardized relative position within the same group to determine whether EUI was high or low. An annual energy-saving ratio $R(Q_i)$ was assigned based on the building's own annual EUI in 2023 and its percentile Q_i within its group, as shown in Equation (2).

$$EUI_{target,i} = EUI_{actual,i} \times [1 - R(Q_i)] \quad (2)$$

Here, $R(Q_i)$ is the energy-saving target function, representing the annual energy-saving ratio corresponding to the percentile, $EUI_{actual,i}$ is the actual EUI of the i th building in 2023, and $EUI_{target,i}$ represents the target EUI of the i th building.

Based on the equations, the future target EUI for each building was identified. Each building starts with its EUI, avoiding the setting of unattainable targets with a single absolute EUI threshold. This mitigates disputes caused by differences in building conditions. The percentile ranking was used to determine the building's energy consumption performance, its energy-saving potential, and the appropriate level of energy-saving pressure it should bear. $R(Q_i)$ can be adjusted at any time according to the energy-saving magnitude required by policy. This allows the exploration of different intensities of energy-saving scenarios and targets within the same framework for each building's energy-saving burden ratio.

This energy-saving target function was derived backwards from several prerequisite target points to create a relationship function that was both feasible and reasonable. The core concepts and target points included the following.

- Setting reasonable energy-saving pressure based on the percentile ranking: The lower Q_i indicates that the building's current energy consumption is relatively low within its group. This may be due to the implementation of many energy-saving improvements or good usage behaviors, so excessive demands must not be placed on it; instead, maintaining the current status or making minor optimizations is sufficient. Conversely, those with a higher Q_i must bear a higher energy-saving ratio. Since buildings with a higher EUI generally have higher relative energy-saving potential and room for improvement, this effectively promotes overall building progress. However, attention must be paid to setting a reasonable magnitude for energy saving to ensure achievability, which must align with government energy-saving policy requirements.
- Alignment with government energy-saving policy goals: The government's current energy-saving policy aims to improve overall building electricity use efficiency by 3% after three years, which simplifies to an average annual energy saving of 1% [8]. With this as a goal, reasonable energy-saving targets can be set for the percentiles. We set the energy-saving ratio for the median ($Q_i = 0.5$) at 1% and the ratio for the worst-performing building ($Q_i = 1.0$) at 3%.

The energy-saving target function must satisfy the above requirements. Among all possible functional forms, we chose a simple and easy-to-understand quadratic function. Based on the three target relationships of $R(0) = 0$, $R(0.5) = 0.01$ and $R(1) = 0.03$, the following energy-saving target function was developed through calculation and derivation, as shown in Equation (3).

$$R(Q_i) = 0.02Q_i^2 + 0.01Q_i \quad (3)$$

$$EUI_{target,i} = EUI_{actual,i} \times \left[1 - (0.02Q_i^2 + 0.01Q_i) \right] \quad (4)$$

Figure 1 shows the energy-saving ratios corresponding to the percentiles in the energy-saving target function. Substituting this energy-saving target function into Equation (2) yields Equation (4), which is the target EUI calculation formula established in this study.

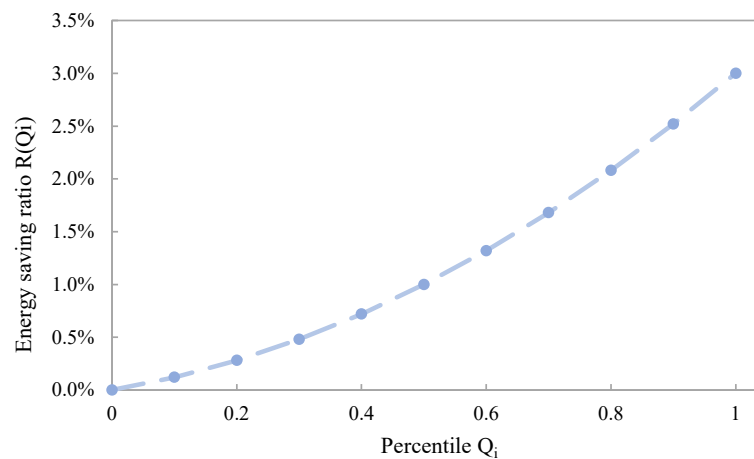


Figure 1. Percentile corresponding to energy-saving ratio.

3. Result and Discussion

3.1. The Actual EUI Distribution

Figure 2 presents the distribution of EUI_{actual} for the three groups, along with the number of buildings with similar EUI. The analysis also provides the mean, standard deviation, and sample size. Figure 2a represents the 8 h group, which is the most common office type, thus having the largest sample size of 1051 records. From the graph and statistical results, it can be observed that the majority of EUI values fall between 30 and 70 kWh/m² year, with an average value of 52.13. A minority of larger EUI values are

distributed between 180 and 360. Figure 2b,c show the EUI distribution for the 10 h and 24 h groups, respectively. The distribution patterns are similar across all three groups, all being right-skewed curves with a small number of extremely large values on the right tail. However, compared with the 8 h group, the EUI values in the 10 h group were more concentrated because these office buildings were central administrative agencies and similar units with larger floor areas. In the 24 h group, the average EUI was the highest of the three, and despite the smaller sample size, continuous operation generally led to higher energy use. Within each group, the EUI distribution remained right-skewed with a long tail and outliers. Such high-EUI buildings at the right tail were the main focus for setting energy-saving targets, encouraging them to reduce consumption and move closer to the bulk of the stock.

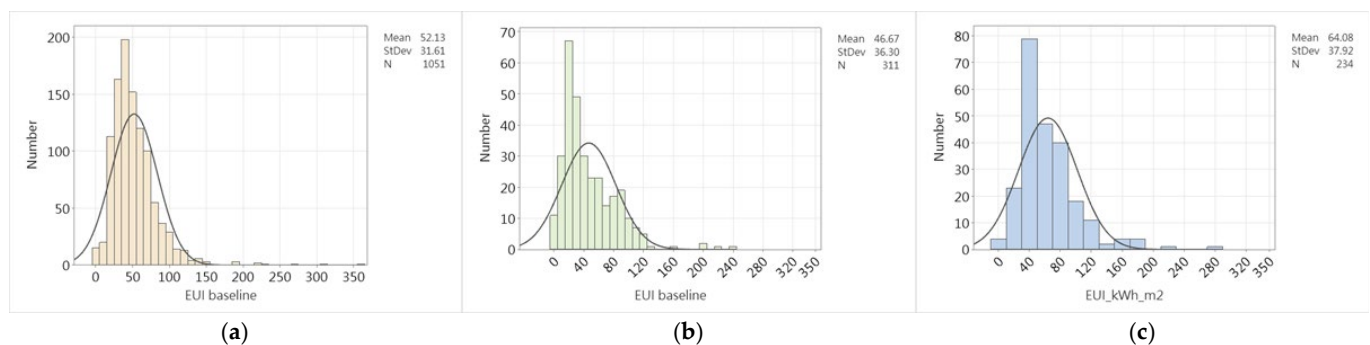


Figure 2. EUI distribution: (a) 8 h; (b) 10 h; (c) 24 h operation.

3.2. Target EUI

Figure 3 displays the distribution of EUI_{actual} and EUI_{target} across the three groups, with paired box plots distinguishing actual baseline (dark) and target values (light).

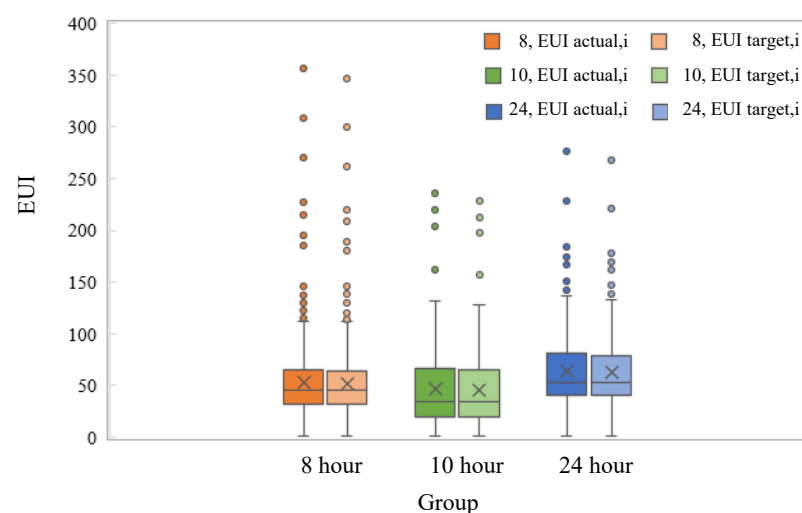


Figure 3. Comparison of EUI before and after setting energy-saving targets.

In all groups, the EUI_{target} box plots shifted downward relative to EUI_{actual} . From the minimum up to the median, the difference between the baseline and target was modest, reflecting a more moderate saving pace for buildings that were already relatively efficient. Above the median, the effect of the increasing saving ratio (starting at 1%) became clearer: the third quartile target was slightly lower than the baseline, especially in the 24 h group, where it decreased by 1.51 kWh/m²·year. The outliers further showed that the function assigned higher saving ratios to high-percentile (high-EUI) buildings, compressing the upper end of the EUI distribution. Although these buildings bore greater saving pressure,

a 3% cap kept targets achievable and allowed for gradual implementation. Furthermore, once EUI_{target} was established, the alignment of the target function with policy goals was examined. By averaging the energy-saving ratio for each building, the average annual energy-saving rate across the three groups, despite different sample sizes, showed only minor variations, all clustering around 1.18%. This is consistent with and slightly more proactive than the current government policy, supporting the validity of the target EUI formulation. If all buildings met their annual targets and EUI_{target} were updated dynamically, the overall EUI would drop by roughly 6%. Even recognizing that in practice only a subset of buildings might reach the target each year, a conservative estimate suggests that the policy goal of a 3% reduction over three years could still be closely approached.

4. Conclusions

In this study, we identified reasonable EUI targets for public buildings as a reference for promoting building energy conservation, strengthening energy management in public offices, and supporting the national net-zero building agenda.

The target-setting framework, driven by operating hours grouping and percentile, tailors energy-saving targets for each building. This approach is simpler and easier to understand compared to methods that use only the median or a single threshold as the energy-saving standard. The developed energy-saving target function and target EUI calculation method are easy to understand and apply, and can be adjusted in response to policy goals, thereby constructing highly adaptable and achievable energy-saving targets. It was found that the EUI distribution is a right-skewed curve. Consequently, a higher proportion of energy-saving responsibility was allocated to high-EUI units, incentivizing their convergence toward the primary cluster.

Author Contributions: Conceptualization, K.-T.H. and P.-L.F.; methodology, K.-T.H. and P.-L.F.; formal analysis, P.-L.F.; resources, K.-T.H. and H.-P.C.; data curation, K.-T.H. and P.-L.F.; writing—original draft preparation, P.-L.F.; writing—review and editing, K.-T.H. and P.-L.F.; visualization, P.-L.F.; supervision, K.-T.H.; project administration, K.-T.H. and H.-P.C.; funding acquisition, K.-T.H. and H.-P.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Foundation of Taiwan Industry Service.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Available on Request.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Yen, C.-J.; Lin, H.-T.; Lee, K.-P. Cost-Effectiveness Analysis of Nearly Zero-Carbon Office Buildings in Taiwan. *Build. Environ.* **2025**, *267*, 112270. [\[CrossRef\]](#)
2. Oikonomou, V.; Becchis, F.; Steg, L.; Russolillo, D. Energy saving and energy efficiency concepts for policy making. *Energy Policy* **2009**, *37*, 4787–4796. [\[CrossRef\]](#)
3. Chung, W. Review of building energy-use performance benchmarking methodologies. *Appl. Energy* **2011**, *88*, 1470–1479. [\[CrossRef\]](#)
4. Chung, W.; Hui, Y.V.; Lam, Y.M. Benchmarking the energy efficiency of commercial buildings. *Appl. Energy* **2006**, *83*, 1–14. [\[CrossRef\]](#)
5. Lee, K.; Lim, H.; Hwang, J.; Lee, D. Development of building benchmarking index for improving gross-floor-area-based energy use intensity. *Energy Build.* **2025**, *328*, 115103. [\[CrossRef\]](#)
6. Turiel, I.; Craig, P.; Levine, M.; McMahon, J.; McCollister, G.; Hesterberg, B.; Robinson, M. Estimation of energy intensity by end-use for commercial buildings. *Energy* **1987**, *12*, 435–446. [\[CrossRef\]](#)

7. Energy Administration, Ministry of Economic Affairs, Taiwan. Government Agencies and Schools Energy Conservation Reporting System. Available online: <https://egov.ftis.org.tw/> (accessed on 30 October 2025).
8. Energy Administration, Ministry of Economic Affairs, Taiwan. *Government Agencies and Schools Electricity Efficiency Improvement Program (2024–2026)*; Ministry of Economic Affairs: Taipei, Taiwan, 2024.

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.