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Case study on Opportunities to Revise Energy Codes by Data Digitization Using a Smart Building Energy Audit Tool With Buildings in Hong Kong

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ABSTRACT

Building energy management is crucial to meet carbon neutrality targets between 2050 and 2060. Yet, building energy management standards and codes are struggling to be updated quickly due to misunderstanding from stakeholders outside the standard and code revision committees. This paper explores opportunities to clarify the misunderstanding through digitization of data collected from statuary submissions for these standards and codes of various buildings. 239 building energy audit cases in Hong Kong between 2019 and 2021 are digitized with a smart energy audit tool and analyzed. The results show not only opportunities to counterargue misunderstanding from the stakeholders on the impossibility to follow proposed standards, they also show new opportunities of new building energy management techniques to further reduce building energy use and to meet carbon neutrality targets.

Keywords: energy audit, energy end use, energy efficiency, energy utilization, building energy management

NONMENCLATURE

Symbols	
A	Area (m^2)
ACEUI	Air-conditioning energy utilization index (MJ/m^2/annum)
COP	Overall coefficient of performance
E_{AC}	Annual electricity consumption of air-conditioning equipment (MJ/annum)
H	Annual operating hour (hr)
LEUI	Lighting energy utilization index (MJ/m^2/annum)
LPD	Lighting power density (W/m^2)
QAC	Rated cooling capacity (W)
QPD	Rated cooling capacity per unit area (W/m^2)
W_{AC}	Rated power consumption of air-conditioning equipment (W)
$W_{lighting}$	Rated power consumption of lighting equipment (W)

1. INTRODUCTION

Building energy management is crucial to minimize building energy use and carbon emission and to support the achievement of carbon neutrality in the decade of 2050 [1]. There are multiple standards and code of practices such as ASHRAE 90.1 [2], IECC [3], CIBSE Guide F [4] and Code of Practice for Energy Efficiency of Building Services Installation [5] to constrain the minimum energy efficiency of equipment installed in buildings to reduce energy use and carbon emission, and these standards and codes of practice are updated every few years. While some studies are dedicated to justify the rationales of these updates [6], the updating methods are largely result-oriented. This leads to speculations from others outside the standard and code revision committees on the viability of the new codes in the revisions, claiming that an update is impossible to implement due to market incapability. These arguments are not easy to counterargue.

One method to justify that the readiness of the market is through data-driven approaches. During the implementation of the standards and codes, information are gathered to ensure project compliance with the standards and codes [7], [8]. The digitization of the data can be used to create an understanding of equipment design from the energy efficiency perspective, and the understanding can be used to see if stricter energy codes can be deployed to further improve energy efficiency of equipment to achieve the energy saving targets.

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This paper gives a case study to clarify the misunderstanding through data digitization. The case study was performed with digital data from a smart building energy audit tool used for buildings in Hong Kong through comparison of the current equipment design with government requirements and exploration of potentially new energy saving measures. Conclusions on the capability of data digitization to update energy codes are made.

2. METHOD OF STUDY

The method of study was performed in 3 steps – data acquisition, metric calculation and data visualization and analysis.

2.1 Data acquisition

The study started by digitizing data from project data used to indicate building design compliance with statuary energy standards and codes. Data digitized included the number of equipment, types of equipment, their ratings, installation locations, operating hours, the area of each room in the premises, the functions of the rooms and their annual electricity consumption.

2.2 Metric calculation

The data were analyzed to calculate the corresponding energy efficiency metrics, including lighting power density (LPD), lighting energy utilization index (LEUI), air-conditioning energy utilization index (ACEUI), overall coefficient of performance of air-conditioning equipment (COP), and rated cooling capacity per unit area (QPD), calculated by Equations (1), (2), (3), (4) and (5) respectively.

$$LPD = \frac{\sum W_{lighting}}{A} \quad (1)$$

$$LEUI = \frac{\sum W_{lighting} H}{A} \times \frac{3600s}{1hr} \times \frac{1}{1000000} \quad (2)$$

$$ACEUI = \frac{E_{AC}}{A} \quad (3)$$

$$COP = \frac{\sum Q_{AC}}{\sum W_{AC}} \quad (4)$$

$$QPD = \frac{\sum Q_{AC}}{\sum A} \quad (5)$$

LPD measured the installation density of lighting equipment in a space. LEUI calculated the amount of lighting energy use density annually and could be compared with energy utilization index to examine the proportion of lighting energy use, while ACEUI calculated that of air-conditioning equipment. COP calculated the energy efficiency of air-conditioning equipment, and QPD measured how much cooling was provided per unit area of space.

2.3 Data visualization and analysis

The metrics were analyzed by plotting against each other and plotting their population distribution against the limits in existing standards.

2.4 Description of the case study scenario

This case study digitized 239 energy audits cases from 2019 to 2021 in Hong Kong using our in-house smart building energy audit tool during the validity period of the Code of Practice for Energy Efficiency of Building Services Installation 2018 (BEC 2018) [5]. These cases included 90 offices, 14 restaurants and other types of premises.

3. RESULTS AND DISCUSSION

While the analyses were conducted with more than 20 types of indoor spaces, for simplicity, only the results of two types of spaces were shown for each analysis.

3.1 Lighting power density and lighting energy utilization index

The lighting power density and lighting energy utilization index of conference and seminar rooms in the energy audit cases are plotted in Fig. 1 and Fig. 2.

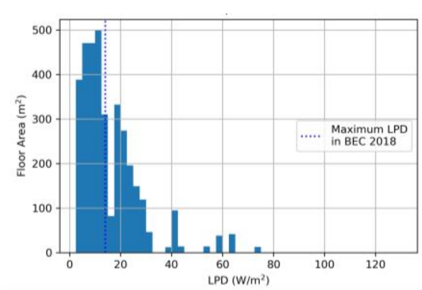

Fig. 1. LPD distribution relative to maximum LPD permitted in BEC 2018 in conference and seminar rooms

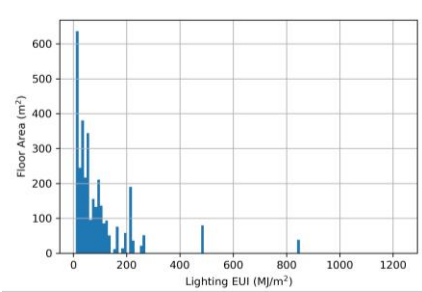

Fig. 2. LEUI distribution in conference and seminar rooms

Fig. 1 shows that there is potential for lower LPD for conference and seminar rooms because more than 50% of conference and seminar rooms in the cases can satisfy the requirement. Yet, Fig. 2 shows that the LEUI is not high relative to the approximately 500 MJ/m^2 energy utilization index benchmarks in offices in Hong Kong [9]. The result shows that its reduction would not bring significant building energy use reduction.

Fig. 3 and Fig. 4 shows a similar analysis for offices.

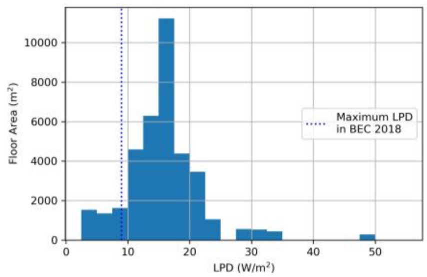

Fig. 3. LPD distribution relative to maximum lighting power density permitted in BEC 2018 in offices

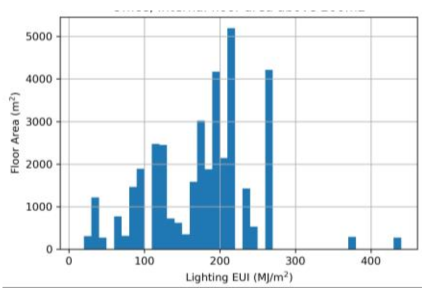

Fig. 4. LEUI distribution in offices

While Fig. 3 shows that most of the current office designs may not fit the BEC requirement in LPD, Fig. 4 shows that its lighting energy utilization index is high relative to the 500 MJ/m^2 benchmark for offices in Hong Kong. A further study is shown in Fig. 5.

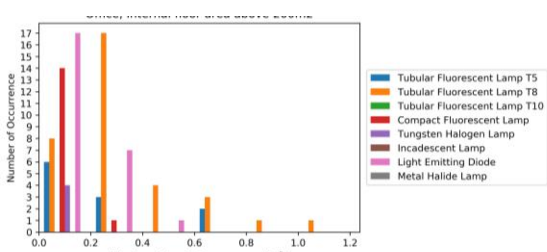

Fig. 5. Types of lighting equipment in offices

Fig. 5 shows that the high LPD and LEUI are results of low usage of light emitting diode that are widely available in Hong Kong. Despite the non-compliance cases, the data show that the technologies allow further reduction of LPD. Based on the emission factor in Hong Kong [10], a reduction of LPD of the offices to the BEC limit in Fig. 3 should induce more than 82.6 MJ/m^2 energy use reduction and 16.1 kg-CO_2e/m^2 carbon emission reduction in office and banks.

3.2 Air-conditioning energy utilization index, overall coefficient of performance and rated cooling capacity per unit area

COP and QPD are also plotted with ACEUI for opportunities to reduce air-conditioning energy use. One example for banks and offices with no external cooling sources is shown in Fig. 6 and Fig. 7.

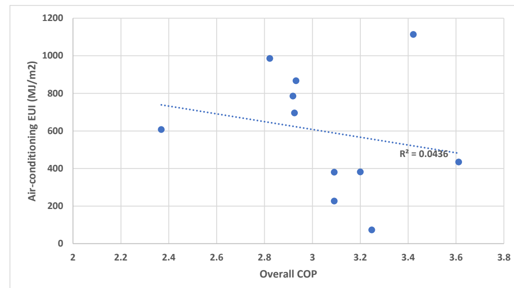

Fig. 6. COP of air-conditioning equipment in banks and offices versus ACEUI

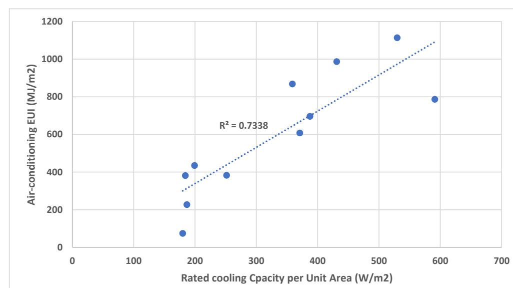

Fig. 7. QPD of air-conditioning equipment in banks and offices versus ACEUI

While Fig. 6 shows that air-conditioning energy use is related with COP, Fig. 7 shows a stronger relationship between QPD and ACEUI. However, in current energy standards and codes [2]–[5], QPD is not regulated. The data also shows a much larger value of QPD than a prior estimation at 117 W/m^2 for typical commercial buildings for policy making in Hong Kong in 2014 [11]. This shows the need for data digitization to update city energy performance for effective energy use and carbon emission reduction policy making.

Similar analyses can be obtained in data of community centers with Fig. 8 and Fig. 9.

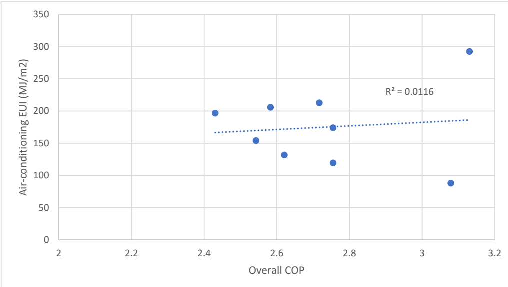

Fig. 8. Overall COP of air-conditioning equipment in community centers versus ACEUI

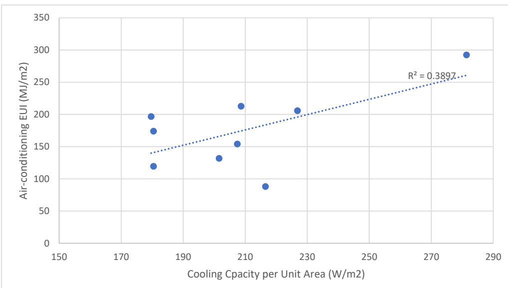

Fig. 9. QPD of air-conditioning equipment in community centers versus ACEUI

The above analyses show opportunities for higher building energy efficiency if maximum QPD is regulated in the same way as LPD and COP. For example, if a maximum QPD is set for banks and offices at 300 W/m^2, based on Fig. 7, the range of carbon emission reduction can vary from 14.9 kg-CO_2e/m^2 to 113.2 kg-CO_2e/m^2 and are equivalent to energy reduction in the range of 76.5 MJ/m^2 to 582.1 MJ/m^2. This reduction is larger than that by LPD reduction shown in Section 3.1.

4. CONCLUSIONS

This paper presents a case study of applications of digitization of building data from statuary submissions for building energy standard and code compliance. The case study was conducted by digitizing 239 building energy audit cases in Hong Kong with a smart energy audit tool, and the analysis was performed on its lighting and air-conditioning equipment operation. Example results show the followings:

1) There is market feasibility for maximum LPD reduction and other technological constraints for energy saving and carbon emission reduction;

2) Potentially new energy saving measures such as maximum rated cooling capacity per unit area to reduce air-conditioning energy use and carbon emission can be suggested;

3) Regular data digitization of energy equipment design in buildings is necessary for correct and effective policy making.

These example results prove that digitization of building data from statuary submissions for building energy standard and code compliance supports their revision through clarification and exploration of new measures, supporting further building energy use reduction to achieve carbon neutrality.

ACKNOWLEDGEMENT

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