Benchmarking Energy Efficiency by 'Space Type':
An Energy Management Tool for Individual Departments Within Universities

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Abstract
‘Energy management’ is a challenging task for individual departments within universities, especially when several departments occupy the same facility. To assist individual departments in dealing with the complex energy management topics, this study aims to establish the Benchmarking Energy Efficiency by Space Type (BEEST) method. The BEEST is developed around the core concept of ‘space type’. It is proposed that the spaces within a department be categorized into several ‘space types’; and for each space type, its 'standard operation settings' be defined to further estimate the 'standard energy consumption' for the department, with energy prediction module such as eQuest, as its energy consumption benchmark. The energy efficiency index of a department and its facility can then be assessed by comparing its 'actual energy consumption' against the estimated 'standard energy consumption. The problem areas can be identified and energy saving action plans recommended by conducting further analyses, such as energy analyses by space types, floors, and equipment types as well as sensitivity analyses of the energy reduction effects of various 'standard settings'. The Department of Architecture of the national university NTUST in Taiwan is used as a case to demonstrate how the BEEST functions as an effective energy management tool.

Keywords: facility management; standard operation settings; standard energy consumption; energy efficiency index

1. Introduction
'Energy management' has become an important facility management issue for universities in Taiwan. Individual departments within universities are usually held responsible for managing the energy efficiency of their facilities. This becomes an even more challenging task when several departments occupy the same facility. Two obstacles lie in front of individual departments. First of all, the actual amount of energy consumed by each department is usually unknown and hard to estimate: The actual energy consumption of a ‘facility’ might be measured and monitored; but the actual energy consumptions of the ‘individual departments’ in the same facility would be difficult to estimate correctly, due to the different work processes and energy demands that might exist among these departments. Secondly, individual departments lack reasonable energy consumption benchmarks or indices. For example, the national average of energy use intensity for universities (EUI, 120.8 kWh/m²-yr) is the only referable benchmark. However, this benchmark has failed to become an effective reference. As revealed by an earlier domestic study, the energy consumptions of the thirteen buildings in a certain university varied greatly (ranging from 63.6 to 220.1 kWh/m²-yr), due to large variances in building characteristics, occupancy use patterns and energy needs among different departments (Tu et al., 2010). In such a case, the national average EUI 120.8 kWh/m²-yr is meaningless for those departments/ buildings with lower EUIs and may be unattainably low for those with extremely high EUIs. Individual departments need an effective energy management tool that is capable of establishing reasonable energy consumption benchmarks catering to departments' functional and energy needs as well as diagnosing the energy performance of departments' facilities.

To assist individual departments in their complex energy management tasks, this paper aims to develop the Benchmarking Energy Efficiency by Space Type (BEEST) method. The core concepts of the BEEST methodology will be described, and the procedures and results of applying the BEEST will be demonstrated, step by step, in a case (the Department of Architecture of the national university NTUST).

2. Literature Review
This study has reviewed the existing literature focusing on the energy management aspects of 'existing buildings' and categorized them into two
groups based on their research objectives. The first group involved diagnosing the energy efficiency of a 'building or system', proposing improvement plans (such as installing external shading devices), and employing energy simulation software to assess the magnitude of energy savings achieved by various plans (Zhu, 2006; Hatamipour, 2007; Sun and Lee, 2006). The approaches taken often involve in-depth investigation and large scale refurbishment, and incur high costs. They thus are not useful for departments in universities, who simply need a tool to perform preliminary evaluation on the energy efficiency of their facilities and to identify problem areas first.

The second group of studies typically involved developing energy efficiency scales or evaluation methods to measure and compare the energy efficiencies of various buildings. For example, in Hong Kong, the Building Environmental Assessment Method (HK-BEAM) was developed to measure the energy performance of buildings against the 'baseline building' (Lee et al., 2007); besides, a ten-level scale was defined to assess the energy efficiency of supermarket facilities (Chung et al., 2006). In the Netherlands, the EPA-ED was established to measure the energy efficiency of existing housing and establish national energy consumption benchmarks (Poel et al., 2007). In Sweden, energy consumption benchmarks for two different classes of hotel chains were developed respectively (Bohdanowicz and Martinac, 2007). In Singapore, a three-level energy efficiency scale was established and criteria defined for office buildings (Haji-Sapar and Lee, 2005). In summary, these energy efficiency scales produced an 'efficiency score' to indicate the energy performance at the 'building' level; yet they fail to inform a 'department', that often occupies only a certain floor of a building, much about the energy efficiency of its facility.

3. Methodology of the BEEST

Several core concepts underlie the methodology of the BEEST. First of all, it is proposed that the spaces in a department be classified into several 'space types'. Then, for each space type, its typical 'standard operation settings' such as occupancy use patterns, environmental quality, building systems and equipment characteristics are defined and used to estimate the 'standard energy consumption' of the department (regarded as its energy consumption benchmark). Then, its 'actual energy consumption' is compared against its 'standard energy consumption' to yield its 'energy efficiency index', indicating the overall energy performance of the department and its facility.

3.1 Space type

A department in a university in Taiwan often occupies a portion of a facility (across several floors). Usually, the spaces within a department can be categorized according to their occupants and 'functional uses' (Fig.1.). In the same type of space, the tasks and processes performed by its occupants, the occupancy use patterns (operation schedule and occupant density), task-supporting equipment, as well as the environmental quality needed could be quite similar. This paper thus argues that the energy consumptions (per square meter) of the same type of space may be quite close, if other variables such as external weather conditions, building envelope and building control systems are kept the same. Conceptually, an effective yet reasonable 'standard energy consumption' can be identified and established as the benchmark of each space type. The 'standard energy consumption' of all types of spaces of a department can then be added up to the 'standard energy consumption' for the department.

Fig.1. Core Concepts of the BEEST: Type of Space, Standard Settings, Standard Energy Consumption and Energy Efficiency Index
3.2 Standard settings & standard energy consumption

This study has proposed that the following 'standard operation settings' be defined for all 'space types' in a department (Fig.1.):

1. Standard environmental quality: the preferred illuminance of each space type; set point temperature of the HVAC systems.
2. Standard lighting system scheme: lighting fixture type and fixture density of each space type.
3. Standard occupancy use patterns: the occupant density, schedule profile, major equipment density, and supplementary equipment density of each space type.

Conceptually, these 'standard settings' are defined in such a way that they represent the most reasonable and effectively regulated way of operation (energy-wise) for each space type. Consequently, a certain type of space operating under its 'standard settings' is expected to consume the least amount of energy possible, i.e. the 'standard energy consumption' of that space type. The summation of the standard energy consumptions of all spaces is defined as the 'standard energy consumption' of the department (Fig.1.). Similarly, it represents the minimal energy consumption of the department, and is considered as the energy efficiency benchmark for the department (measured in kWh/m² -yr or -month, same as EUI).

The 'standard EUI' of a 'space' is affected not only by its 'standard settings' but also other factors such as the existing external weather conditions, building characteristics (orientation, floor dimensions, building envelope, etc), and HVAC system schemes. It is suggested that data of all factors of all types of spaces be input to and modeled by various energy simulation software (ex. eQuest) or energy prediction models.

3.3 Energy efficiency index

The 'energy efficiency index' (EEI) of a department, defined as the ratio of its 'actual EUI' to its 'standard EUI' (%), is used to indicate the energy performance of a department and its facility (Fig.1.). Since the 'actual EUI' is usually larger than the 'standard EUI', the EEI of a department normally exceeds 100%. The larger the EEI is, the less energy efficient a department is. When the 'actual EUI' of a department can not be physically measured, it is advised that it be estimated by various energy simulation software or other energy prediction models.

The term 'variable energy consumption' is further defined as the 'variable' portion of its 'actual EUI' that exceeds its 'standard EUI' (calculated by subtracting its 'standard EUI' from its 'actual EUI'). It is equivalent to the portion of the EEI that exceeds 100% and represents the portion of energy that can be potentially saved. For example, an EEI of 120% means that the 'variable EUI' is 20% of its 'standard EUI'; and the department has a 20% energy saving potential if its 'existing operation conditions' can be changed to its 'standard operation settings'.

4. Theoretical framework of the BEEST

Implementing the above core concepts, the Benchmarking Energy Efficiency by Space Type (BEEST) method was developed to assist institutions or departments in diagnosing the energy performance of their facilities. The theoretical framework of the BEEST consists of three major parts (Fig.2.).

4.1 Input data

The BEEST collects the following three types of input data from a department (Fig.2.):

1. Existing climate and building infrastructure: include the climate conditions around the site, building envelope characteristics of the building, and HVAC system schemes installed in the occupied spaces. These are considered the 'fixed' building conditions given to the department and are less likely to alter due to the high costs typically involved.
2. Existing operation conditions: include the existing status of the environmental quality, lighting system schemes, and the occupancy use patterns in all space types. These are considered the 'actual and usual' conditions under which the department is operating. These data along with the 'existing climate and building infrastructure' data are used to estimate the 'actual EUI' of the department.
3. Standard operation settings: include the 'standard settings' of the environmental quality, lighting system schemes, and occupancy use patterns in all space types. These are considered the 'fixed' building conditions given to the department and are less likely to alter due to the high costs typically involved.

The BEEST collects the following three types of output data for a department (Fig.2.):

1. Energy consumption estimates: 'Actual EUIs' and 'standard EUIs' for the whole department and for each floor are estimated. Then the 'variable EUI' of the department and each floor are also calculated (subtracting standard EUIs from actual EUIs).
2. Energy efficiency index (EEI): The EEIs of the 'whole department' and 'each floor' are calculated (the ratio of the actual EUI to standard EUI).
3. Energy performance analysis: 'energy analysis by equipment type' is performed to identify the major
5. Demonstration

The Department of Architecture (DA) of the national university NTUST, is used as a case to demonstrate, step by step, how the BEEST functions as an effective energy management tool.

There are about 350 occupants in the Department (17 full time faculty members, 10 research assistants, three full time administrative staff, 200 undergraduate students, and 120 graduate students). The department occupies the 7th, 8th and 9th floors of the Research Building on campus (Fig.3.).

NTUST is located in Taipei City with a humid subtropical climate. The average temperature in summer is 29.4 °C and in winter 11 °C. Summers are hot (133 days in a year with maximum temperature exceeding 30 °C) and humid (mean relative humidity 74.0~81.1%), and accompanied by occasional rainstorms and typhoons. Winters are short and mild. Taipei’s average annual sunshine is 1,408 hours (67% of the time is cloudy), and average annual precipitation is 2,325 mm (46% of the days in a year rain).

Step 1: Classify spaces

There are a total of 66 spaces in the Department, taking up a total of 3,386 m² of floor area. These spaces were classified into seven major types according to their 'functional uses': administrative office, faculty office, research lab (for graduate students), design studio (for undergraduate students), classroom, workshop and service (lobby, corridor, elevator, toilet and staircase). The major differences in the number of each space type among the three floors are highlighted by the bold numbers in Table 1.

Step 2: Investigate existing building conditions

Two main types of existing conditions of the 7th, 8th and 9th floors the DA occupies were then investigated:

- 'Actual EUI'
- 'Standard EUI'
- 'Variable EUI'
- 'Energy prediction module' or energy simulation software (ex. eQuest)

Table 1. The Number and Area of Each Type of Space in the Department of Architecture, NTUST

| Type of space   | 7th fl. Number | Area (m²) | 8th fl. Number | Area (m²) | 9th fl. Number | Area (m²) | Total Number | Area (m²) |
|----------------|----------------|-----------|----------------|-----------|----------------|-----------|--------------|-----------|
| Administrative (AD) | 0              | 0         | 3              | 264       | 0              | 0         | 3            | 264 (7.8%)|
| Faculty office (FO) | 5              | 99        | 5              | 98        | 6              | 122       | 16           | 319 (9.5%)|
| Research lab (RL) | 2              | 207       | 3              | 202       | 3              | 205       | 8            | 614 (18.2%)|
| Design studio (DS) | 4              | 502       | 0              | 0         | 2              | 276       | 6            | 778 (23.0%)|
| Classroom (CR) | 0              | 0         | 1              | 203       | 2              | 236       | 3            | 439 (13.0%)|
| Workshop (WS) | 0              | 0         | 0              | 0         | 1              | 30        | 1            | 30 (0.4%) |
| Service (SV) | 8              | 310       | 12             | 339       | 8              | 293       | 28           | 942 (28.0%)|
| **Total** | **19**         | **1,118** | **24**         | **1,106** | **23**         | **1,162** | **66**       | **3,386** |

equipment types consuming the most energy and their energy saving potentials for a department. 'Sensitivity analyses' are performed to assess the energy saving effects of the four sets of 'standard operation settings' (schedule, occupant, equipment, and set point temperature) for all types of spaces.
1. Existing climate and building infrastructure:
- Climate: the weather data file of the 'typical meteorological year' of Taiwan, containing hourly weather data of twenty four climatic items in Taipei area, was used for energy prediction.
- Building characteristics: building orientation, floor plate dimensions, floor height (m), envelope construction and materials, surface area, opening percentage of fenestration (%), U-value (W/m²-K), and shading coefficient of fenestration of the Research Building were recorded (Table 2).
- Building system schemes: For each space type, the data of the major types of HVAC system, their refrigeration capacity (ton) and energy efficiency ratio (EER), as well as the type and the average density of the artificial lighting fixtures (watt/m²), were investigated (Table 3).

2. Existing operation conditions: for each space type, the existing conditions of ‘occupancy use patterns’, such as occupant density (m²/ per), occupancy schedules and HVAC operation schedules (weekday, weekend, summer weekday, summer weekend), primary and miscellaneous office equipment densities (watt/m²), as well as ‘environmental quality’, such as HVAC set point temperature, on the three floors were collected (Table 4).

Step 3: Establish the 'standard operation settings'
For demonstration, only the following two types of 'standard operation settings' were defined for each space type in the DA in this study (the same as in step 2-2, 'lighting system schemes' not included, Table 5):  
1. Occupancy use patterns: occupant density (m²/ per), occupancy schedules and HVAC operation schedules (weekday, weekend, summer weekday, summer weekend), primary and miscellaneous office equipment densities (watt/m²);  
2. Environmental quality: HVAC set point temperature

Step 4: Estimate departmental energy consumption
The energy simulation software eQuest V.3 was employed as the 'energy prediction module' to simulate and estimate the 'actual' and 'standard' energy consumptions of the Department.  
1. The estimated 'actual EUI': As shown in Table 6., the total annual energy consumption of the DA is 606,890 kWh/yr. The 'actual EUI' of the DA is 180.0 kWh/ m²-yr, almost 50% higher than the national average EUI for universities (120.8 kWh/m²-yr). The 'actual EUIs' of the three floors do not vary a lot, ranging from 170.1 kWh/m²-yr (8th floor) to 188.0 kWh/m²-yr (6th floor). Theoretically, the differences in the 'actual EUIs' of the three floors are mainly caused by the differences in the 'space types', 'building system schemes' and 'actual occupancy use patterns' among the three floors.  
2. The estimated 'standard EUI': As shown in Table 6., the 'standard EUI' of the DA is 132.7 kWh/m²-yr, and the 'standard EUIs' of the three floors vary a lot. The 'standard EUI' of the 8th floor is 161.9 kWh/m²-yr, much higher than those of the 7th and 9th floors (117.8 and 119.2 kWh/m²-yr). This means, the 8th floor inherently requires more energy to operate than the other two floors, given the tasks to be performed, existing climate and building infrastructure, and pre-defined 'standard operation settings'. In theory, the differences in the 'standard EUIs' of the three floors are mainly caused by the differences in the 'space types', 'building system schemes', 'actual occupancy use patterns', and 'standard operation settings' among the three floors.  
3. The estimated 'variable EUI': As shown in Table 6., the 'variable EUI' of the DA was estimated to be 47.3 kWh/m²-yr, and there are large variations in 'variable EUIs' among the three floors. The 'variable EUI' of the 8th floor (26.1 kWh/m²-yr) appears to be much less than those of the 7th and 9th floors (64.5 and 50.9 kWh/m²-yr). This means the potential for energy saving on the 8th floor is not as large as those on the other two floors.

Step 5: Diagnose departmental energy performance

Energy efficiency index (EEI)
The 'energy efficiency indices' of the Department were reviewed at 'department' and 'floor' levels:  
1. Assessing the energy efficiency at department level: The EEI of the DA is 135.6% (Table 6. and Fig.4.), indicating that 'existing operation conditions' have resulted in an energy consumption level 35.6% higher than one operating under 'standard operation settings'. In other words, there is a 35.6% energy saving potential if the DA decides to change and operate under the 'standard operation settings'.  
2. Assessing the energy efficiency at floor level: As shown in Table 6. and Fig.4., the EEIs among the three floors vary greatly. The EEI of the 8th floor is 116.1%, much less than those of the 7th and 9th floors (154.8% and 142.7%). Although the 8th floor consumed more energy (higher EUI), it is considered more energy efficient than the other two floors (lower EEI, less energy saving potential). On the contrary, although the 7th and 9th floor consumed less energy, they are not as efficient because their EEIs are higher. There is a 40–50% of energy saving potential on both floors.

Energy analysis by equipment type
The 'actual EUIs' and 'standard EUIs' of the three floors in the DA were broken down by three major equipment types (lighting, miscellaneous equipment, and HVAC). As shown in Table 7., the HVAC system consumed almost half of the 'actual EUI' (48.9%), whereas the lighting system and miscellaneous office equipment consumed similar amounts of energy (25.8 and 25.3% respectively). The further comparisons of the 'actual EUIs' and the 'standard EUIs' broken down by equipment types among three floors indicate that 'HVAC' is identified as the major energy saving target on all three floors (potential energy savings of 49.9, 25.2 and 35.0 kWh/m²-yr); and 'miscellaneous office
Table 2. The Existing 'Building Characteristics' of the Research Building, NTUST

| Orientation | Floor Plate | Floor Height | Envelope construction | Surface area | Fenestration percentage | Fenestration U-value & SC |
|-------------|-------------|--------------|-----------------------|--------------|-------------------------|--------------------------|
| 7th floor   | SE-NW       | 48m*31m      | 15cm RC wall + tile   | SE: 196m²    | SE: 27.9%               | Single glazed clear, aluminum |
| 8th floor   |             | 4.0 m        |                       | SW: 115m²    | SW: 0.4%                | U = 7.4 W/m²·K            |
| 9th floor   |             |              |                       | NE: 115m²    | NE: 11.9%               | SC = 0.79                |

Table 3. The Existing 'Building System Schemes' for Each Space Type on the Three Floors of the DA, NTUST

| Type of space | Type               | Cooling capacity (ton) | Energy efficiency ratio (EER) | Light fixture type (w/m²) | Lighting density (w/m²) |
|---------------|--------------------|------------------------|-------------------------------|---------------------------|-------------------------|
| 7th floor     |                    |                        |                               |                           |                         |
| 8th floor     |                    |                        |                               |                           |                         |
| 9th floor     |                    |                        |                               |                           |                         |

Table 4. The 'Existing Operation Conditions' for Each Space Type on the Three Floors of the DA, NTUST

| Type of space | Occupancy density (m²/person) | Occupancy schedule (hour) | HVAC operation schedule (hour) | Primary office equip density (watt/m²) | Misc. office equip. density (watt/m²) | HVAC set point temperature (°C) |
|---------------|-----------------------------|---------------------------|--------------------------------|----------------------------------------|----------------------------------------|-------------------------------|
| 7th floor     |                             |                           |                                |                                        |                                        |                               |
| 8th floor     |                             |                           |                                |                                        |                                        |                               |
| 9th floor     |                             |                           |                                |                                        |                                        |                               |

Table 5. The 'Standard Operation Settings' for Each Space Type on the Three Floors of the DA, NTUST

| Type of space | Occupancy density (m²/person) | Occupancy schedule (hour) | HVAC operation schedule (hour) | Primary office equip density (watt/m²) | Misc. office equip. density (watt/m²) | HVAC set point temperature (°C) |
|---------------|-------------------------------|---------------------------|--------------------------------|----------------------------------------|----------------------------------------|-------------------------------|
| 7th floor     |                              |                           |                                |                                        |                                        |                               |
| 8th floor     |                              |                           |                                |                                        |                                        |                               |
| 9th floor     |                              |                           |                                |                                        |                                        |                               |

Table 6. Various Energy Consumption Estimates for the Three Floors of the DA, NTUST

| Floor | Annual energy consumption (kWh/yr) | Actual EUI (kWh/m²·yr) | Standard EUI (kWh/m²·yr) | Variable EUI (kWh/m²·yr) | Energy efficiency index |
|-------|-----------------------------------|------------------------|-------------------------|--------------------------|------------------------|
| 7th fl.|                                  | 203,900               | 182.4                  | 117.8                    | 64.5                   | 154.8%                   |
| 8th fl.|                                  | 207,920               | 188.0                  | 161.9                    | 26.1                   | 116.1%                   |
| 9th fl.|                                  | 195,070               | 170.1                  | 119.2                    | 50.9                   | 142.7%                   |
| Total / Ave |                              | 606,890               | 180.0                  | 132.7                    | 47.3                   | 135.6%                   |
Fig. 4. The 'Standard EUIs' and 'Variable EUIs' for Showing the Energy Consumption Characteristics and Energy Saving Potential on the Three Floors of the DA, NTUST

Table 7. The 'Actual EUIs' and 'Standard EUIs' Broken down by Floor and by Equipment Type in the DA, NTUST

| Floor | Lighting | Equipment | HVAC | Total | Lighting | Equipment | HVAC | Total |
|-------|----------|-----------|------|-------|----------|-----------|------|-------|
| 7th fl | 44.1     | 39.6      | 98.7 | 182.4 | 40.5     | 26.5      | 48.8 | 117.8 |
| 8th fl | 52.6     | 54.2      | 81.3 | 188.0 | 48.4     | 57.4      | 161.9 |
| 9th fl | 42.7     | 43.2      | 84.2 | 170.1 | 39.3     | 30.7      | 49.2 | 119.2 |
| Total   | 46.4     | 45.6      | 88.0 | 180.0 | 42.5     | 38.6      | 51.1 | 132.7 |
| Average | 25.8%    | 25.3%     | 48.9% |       | 29.2%    | 38.7%     |      | 100.0% |

Fig. 5. The Energy Saving Potentials of the Three Major Types of Equipment on the Three Floors of the DA, NTUST

Table 7. The 'Actual EUIs' and 'Standard EUIs' Broken down by Floor and by Equipment Type in the DA, NTUST

- **Sensitivity analysis**

  Four sets of standard operation setting' for all space types (standard occupancy schedule, standard occupant density, standard equipment density and standard set point temperature) were inputted, set by set, to eQuest to assess the energy saving effects of each set of standard settings on the three floors (Fig. 6.). It is found that major energy saving effects can be achieved by moving from 'existing set point temperature' towards 'standard set point temperature' on three floors (resulting in 62.3%, 98.8%, and 63.8% of energy reduction). Secondary energy saving effects can be achieved by moving towards 'standard occupancy schedule' on three floors (40.1, 76.1, and 25.5% of energy reduction).

**Step 6: Recommended energy saving action plans**

The numbers in the 'existing operation conditions' (Table 4.) and 'standard operation settings' (Table 5.) were compared to identify the 'settings' and 'space types' yielding the largest energy saving potentials (indicated by bold numbers in both tables). Based on the analytical results shown in Step 4 and 5, this paper recommends the following energy saving action plans:

1. The 'actual EUI' of the DA is 180.0 kWh/m²-yr, 50% higher than the national average EUI for universities (120.8 kWh/m²-yr). It is suggested that actions be taken to reduce its energy consumption to the 'standard EUI' target (132.7 kWh/m²-yr).

2. The 'actual EUI' of the 7th floor is 182.4 kWh/m²-yr, close to departmental average. However, it has the lowest 'standard EUI' (117.8 kWh/m²-yr) and highest EEI (154.8%), indicating that it has a large potential for energy saving (54.8%). The action plans recommended are: (1) *Research Lab* and *Design Studio* spaces operate under the 'standard set point temperature' (28°C); (2) *Design Studio* and *Service* spaces operate under their 'standard occupancy schedule' (shorter hours); (3) *Faculty Office* spaces operate with 'standard equipment density' (lower density). These action plans should result in major energy reduction from the amounts used by HVAC and miscellaneous office equipment (bold numbers in Table 7.).

3. Although the 8th floor has the highest 'actual EUI', it also has the highest 'standard EUI' (161.9 kWh/m²-yr). Its EEI is 116.1%, indicating that it is more efficient than the other two floors and there is only 16.1% of energy saving potential. The action plans recommended are: (1) *Research Lab* spaces operate under its 'standard set point temperature' (28°C); (2) *Faculty Office* and *Service* spaces operate with their 'standard occupancy schedule' (shorter hours). These plans should result in major energy reduction from what is used by HVAC (Table 7.).

4. The 9th floor has the lowest 'actual EUI' (170.1 kWh/m²-yr). However, its EEI is as high as 142.7%, indicating that it also has a large potential for energy saving (42.7%). It is advised that its energy consumption be reduced to its 'standard EUI' (119.2 kWh/m²-yr). The recommended action plans are: (1) *Research Lab* and *Design Studio* spaces operate under their 'standard set point temperature' (28°C);...
It is proposed that the spaces within a department be classified into several 'space types', and for each space type, its 'standard operation settings' be defined to further estimate the 'standard energy consumption' for the department as its energy benchmark. Several energy analyses, such as the energy efficiency index, equipment analysis, and sensitivity analysis, can then be performed to assess the energy efficiency of the department, to identify problem areas (by spaces, equipment types, operation settings), and to recommend energy saving action plans. The Department of Architecture of NTUST was used as a case to demonstrate, step by step, how the BEEST can effectively assist the department in performing various energy management tasks.

This paper has contributed to the research field of 'energy and buildings' by developing an effective tool to assist individual departments within universities in dealing with the complex energy management tasks. To further validate and improve the BEEST method, it is suggested that the 'actual energy consumptions' of all 'space types' of the DA of NTUST be measured and monitored (estimated by eQuest in this study); and the DA's energy performance be periodically analyzed by the BEEST and compared with this study.

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