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# Performance evaluation of an energy efficient educational building in India

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*ABSTRACT: Buildings consume 33% of total energy (24% domestic and 9% commercial) in India and this is growing at 8% per annum. Reliance on fossil fuel and increasing demand for energy has led to having an unregulated energy use in buildings in India. Despite multiple instances of green buildings existing throughout India wide-scale adoption of green building practices have not been observed. This leads to higher than predicted energy use. Building Performance Evaluation is essential to reduce this gap and help buildings perform better. Despite the improvements in building systems and services, energy efficient building design and implementation – there is a growing gap observed between the intended and actual performance of buildings leading to higher than expected energy use. The purpose of this study is to understand this performance gap for a university building. The study evaluates the actual performance of this building through on-site measurements and provides feedback for the building to perform better.*
*KEYWORDS: Performance evaluation, Educational building, Performance goals, Monitoring, On-site measurements*

## 1. INTRODUCTION

India is experiencing an unprecedented construction boom. It is estimated that the total constructed built-up area in India would increase by nearly five times from 2005 to 2030 [1]. The International Energy Agency (IEA) reported that buildings in India are responsible for 41% of total electricity. The need of the hour is to reduce the environmental impact of buildings and this makes energy efficient buildings an imperative for all future construction in India.

Current codes and rating systems do not have a mandatory evaluation procedure to validate the energy performance through the life of the building. Studies indicate one of the most important reasons for this gap is the lack of proper input by energy consultants, architects, and engineers at various stages of building. This is especially true in India where various stages of construction process happen in isolation. A stringent methodology that helps to embed Building Performance Evaluation (BPE) in the design process is essential to reduce the performance gap. The purpose of this study is to understand the reasons for a gap for Indian context through one case study building.

## 2. SCOPE OF RESEARCH

A recently-built and occupied university building (academic block) located in hot and dry climate for India is selected for evaluation. This building is a certified building with performance targets. This study will help understand factors that lead to performance gap. This study is part of the Newton Fund sponsored UK-India Learn-BPE project and the methodology steps are based on the UK BPE methods developed by Rajat Gupta and Matt Gregg [2, 3].

## 3. METHODOLOGY

The methodology for this study includes the groundwork for monitoring the building which includes instantaneous measurements, logging, surveys, and interviews. The following steps elaborate the methodology followed:

- Understanding the design intent of the building
- On-site measurements
- Analysis of results to evaluate the performance of the building and uncover discrepancies between design intent and actual performance
- Potential actionable gaps

### 3.1 Performance goals for case study building

The building has a total area of approximately 35,600 m$^2$ with 47% conditioned area and 23% window-to-wall ratio. Types of spaces include labs, classrooms, tutorial spaces, faculty areas, seminar halls, and boardrooms. The goals are divided into assets and operations where design intent focuses on assets and enabling operations, but not directly responsible for the operation. The energy goals for building are listed in Table 1.

*Table 1 Performance goals of building*

| Performance Goal | Asset | Operation |
|---|---|---|
| Light pollution reduction | Interior lighting power densities should not exceed 80% and 50% for building facades and landscape features as defined in the standards. | Non-emergency interior lighting automatically to turn off during non-business hours. Natural override capacity is provided for after-hours use. |

| Performance Goal | Asset | Operation |
|---|---|---|
| Daylight 75% of spaces and views of 90% of spaces | 90% of the spaces have direct lines of sight to perimeter glazing | |
| Optimize energy performance | | Academic block- 43.1% energy savings |
| Controllability of systems- lighting and thermal comfort | 90% of spaces should have manual control switches for lighting, 50% of the occupant have controls for thermal comfort. | Occupant use of controls in spaces |
| On-site renewable | Required 7.5% of total energy- Solar PV | Operating solar PV and proper generation, according to the requirement |

### 3.2 On-site measurements

To evaluate the above-mentioned energy performance goals, several variables were monitored and compared with the design phase variable to understand the gap. Surveys and interviews were carried out to understand the building's use and the system use. Constant involvement of on-site officers helped expedite the process. Table 2 shows the list of on-site measurements which were carried out to evaluate the building.

*Table 2 On-site measurement activities*

| |
|---|
| Walk-through and interviews with the facility manager |
| Photographic survey of components and systems |
| Installing Data Loggers |
| Evaluating renewable energy technologies on site |
| Survey of controls and user- interfaces |
| System installation and commissioning review |
| Data collation |

### 3.3 Data analysis and comparison

The building studied was evaluated based on the performance goals. The findings are divided into design intent vs as-built and operation evaluation. The following summarizes the findings from the field study:

Findings of design intent vs as-built (asset)- Solar Photovoltaic (PV) (10.1% of the total energy consumption) according to the energy requirement are installed on site. 100% of spaces have manual control switches for lighting. 93% of the occupants have access to an operable window. There are no occupancy sensors in the building. 34% of the occupants have a thermostat control for spaces. More than 90% of the spaces have direct lines of sight to perimeter glazing.

Operational effectiveness (non-asset)- Energy performance index for this building is 26.5 kWh/m$^{2}$·year. This cannot be compared to the required energy savings due to the lack of calibrated energy model for comparison. According to the survey of user control interface, all space types had ease of access to the interface.

Fan and lighting control in all spaces were well designed. However, certain spaces (classroom, personal cabin, and open office) did not have access to thermostat control. Uniformity ratio for lighting levels was high (>0.5) in all classroom spaces. For the year of monitoring (2017) annual solar generation is 3% more than required.

### 3.4 Feedback for building operation

For the building to perform better, lighting in the spaces should be properly used, blinds should be not drawn unless there is direct glare. Proper maintenance of ductwork and HVAC systems is required for efficient use of systems. Thermostat for more spaces, if provided, may lead to higher satisfaction of occupants. Proper use of operable windows during winter time is recommended to reduce internal $CO_2$ levels.

## 4. CONCLUSION

This study was carried out to evaluate the performance of an energy efficient institutional building in India. This study helped in understanding the framework required for performance evaluation for buildings in India. The field study was extensive in nature and can be replicated to evaluate green rated institutional buildings in India.

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