A socio-technical performance evaluation of green office buildings in the composite climate of India

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Abstract: India has one of the largest registered green building footprints in the world, yet there are limited studies investigating whether actual energy use and occupant satisfaction in such buildings is meeting expectations. This paper uses a socio-technical building performance evaluation (BPE) approach to assess the actual energy and environmental performance (during monsoon season) of two LEED platinum certified green office buildings located in the composite climate of India. The in-use energy and environmental performance of the buildings was examined using a technical building survey, energy data, environmental monitoring, along with occupant satisfaction surveys. Interestingly results showed that the two case study buildings used less energy annually than design predictions and performed better than comparative benchmarks. Building energy use had a high correlation with cooling degree days. However energy generation systems (rooftop photovoltaic systems) did not perform as intended. Indoor temperatures were found to be lower and CO_2 levels higher in cellular offices, as compared to open plan offices. Occupant survey results revealed that users were satisfied with the overall design of the building, comfort levels and indoor air quality, but perceived indoor lighting to be more than required. Such empirical studies will help to build trust in the Indian building industry, which is currently shy of exposing itself to liability risk resulting from actual building performance.

Keywords: Building performance evaluation, low carbon building, monitoring, LEED, GRHIA

1. Introduction

Rapid growth and urbanization (IEA, 2015), the desire to be comfortable and a changing climate (combined with the compounding feed-back cycle of the urban heat island and air-conditioning (AC)) will, among many things, lead buildings in India to use more energy intensive means for cooling (Kumar et al., 2018). For these reasons, India is an important focus for mitigated energy consumption in buildings and green building certification councils have seen this as an opportunity. The Indian Green Building Council (IGBC) claims that India is the second country in the world with the largest registered green building footprint with over 4,981 projects registered for green building ratings, of which 1,571 certified and fully functional (as of November 2018) (IGBC, 2018). Research, however, continually demonstrates that green building rating and certification systems do not always ensure greater energy performance (Sawyer et al., 2008, Sabapathy et al., 2010), occupant satisfaction (Alborz and Berardi, 2015, Gupta and Gregg, 2016) or better indoor environmental quality (IEQ) over conventional buildings (Tham et al., 2015).

The energy performance gap has been thoroughly demonstrated in international research. Research has shown a LEED (Leadership in Energy and Environmental Design) certified building using twice the energy beyond model predictions in the USA (Chen et al., 2015). In the UK this has been reported as up to nine times the energy predicted for exceptionally energy efficient designed buildings funded by the UK government's Building Performance Evaluation (BPE) programme (Palmer and Armitage, 2014). Also, in India (Sabapathy et al., 2010), LEED certified buildings are not performing as expected with respect to certification, i.e. the LEED Silver and Gold facilities of the same type are performing better than one certified as LEED Platinum. The frequency of the performance gap internationally indicates the necessity to demonstrate claims of efficiency, sustainability and comfort through evaluation in India.

BPE is a useful way to identify, quantify and resolve the gap between 'as-designed' and 'built / in-use' performance through a systematic collection and analysis of qualitative and quantitative information related to fabric performance, energy performance and environmental conditions. BPE can involve feedback and evaluation reviews at every phase of the building delivery from strategic planning to occupancy, adaptive reuse and recycling (Preiser, 2001). This paper seeks to apply a customised post-occupancy BPE approach developed in (Gupta et al., 2019) (I-BPE) for Indian green buildings, to evaluate the actual performance of two high-certification level green office buildings in the composite climate of India, from both technical and occupants' perspectives. Following with the next section, the paper first reviews literature on what has been performed to-date in post-occupancy evaluation (POE) / BPE on non-domestic buildings in India. The paper then introduces the case study buildings and the methods used to evaluate the case studies. The results are then presented followed by a discussion on future application and the conclusion.

2. Review of building performance evaluation in India

As BPE can vary in form, intensity, and length of time required, the following review differentiates between field studies in thermal comfort (FSTC) and POE / BPE but counts them all as performance evaluation studies with something to learn and take forward to improve future building. FSTC differs in that it is used to observe the occupant's immediate response to a building and the immediate measurements taken in relation to that response (Nicol and Roaf, 2005). FSTC generally involves spot readings and predicted mean vote (PMV) analysis. In contrast, POE/BPE collects a long range memory of the occupant's response along with energy and environmental features for a glimpse of the building's performance (Nicol and Roaf, 2005, Bordass et al., 2006) but BPE, beyond POE can also include the entire life-cycle of the building, whereas POE is limited to the life of the occupied building (i.e. post-completion / in-use) (Preiser, 2005).

There is a notable collection of published research that demonstrate the use of BPE-related methods in India. Most of these studies are focussed on FSTC utilising thermal comfort questionnaires, interviews, temperature and relative humidity (RH) logging, and spot measurement devices as tools to evaluate environmental parameters of the buildings. A useful development in the FSTC research has been the customization of clothing (clo) values for the Class-II field experiment protocols for thermal comfort (Indraganti, 2010b, Indraganti, 2010a, Manu et al., 2016, Kumar et al., 2016a, Mishra and Ramgopal, 2014). Interior environment assessment methods in the literature included, spot measurements at the time of survey (Manu et al., 2016, Kumar et al., 2016b), thermal comfort questionnaires (including long-term/seasonal outlook and/or thermal sensation and preference votes) (Manu et al., 2016, Kumar et al., 2016b, Dhaka and Mathur, 2017, Thomas, 2017) and long-term logging/monitoring of temperature , relative humidity and other environmental parameters (Ford et al., 1998, Dhaka and Mathur, 2017). In addition, several studies, of naturally ventilated domestic and non, concluded that occupants are comfortable at temperatures greater than comfort ranges recommended by ASHRAE 55, ISO-7730 standards, and the National Building code of India (Sharma and Ali, 1986, Indraganti, 2010a, Kumar et al., 2016b).

Generally, POE/BPE studies differ from the FSTC in that they include the addition of a long range questionnaire on such variables as work area satisfaction, lighting, productivity, and health (Manu et al., 2016); a review of project information, interviews with key stakeholders (Thomas, 2017); the impact of material changes on the interior environment (Garg et al., 2016); design and system installation review, monitoring plan walkthrough, monthly energy bill collection for one year combined with seasonal energy monitoring, data logging of electricity distribution, spot measurements of lighting, temperature, RH, and envelope temperature (Bhanware et al., 2017); and aggregated, sub-metered and appliance energy consumption monitoring (Batra et al., 2013). The largest gap in BPE methods relate to those generally applied before post-occupancy, e.g. evaluation of systems installation, commissioning, and fabric performance.

Table 1 lists the Indian non-domestic studies and their coverage of BPE elements. The table clearly shows the heavier focus on occupant and environment as opposed to energy with a gap in fabric and systems analysis. Overall, most studies are focused on thermal comfort and less on energy consumption, with little cross-over between the two subjects.

Table 1. Review of Indian non-domestic building evaluation related methods

Building type	Source	Design	Fabric/ system	Energy	Environ.	Occupant
Research facility (n=1)	(Ford et al., 1998)				x	
	(Thomas and Baird, 2006)	x		x		x(BUS[A])
IT facility (LEED/ non-LEED) (n=26)	(Sabapathy et al., 2010)			x		x
Office (n=16)	(Manu et al., 2016)				x(FSTC)	x(FSTC)/ (BUS)
Office (n=14)	(Kumar et al., 2016a)				x(FSTC)	x(FSTC)
Office (n=1)	(Bhanware et al., 2017)	x		x	x	
Office (n=19)	(Dhaka and Mathur, 2017)				x(FSTC)	x(FSTC)
Office (n-4)	(Thomas, 2017)	x			x(FSTC)	x(FSTC)/ (BUS)
Academic (n=1)	(Gupta et al., 2019)	x	x	x	x	x(BUS)

[A]The Building Use Studies (BUS) (ARUP, 2014) methodology obtains feedback data on building performance through a self-completion occupant questionnaire; the results can be compared against a national benchmark database. The questionnaire prompts the respondents to comment on the building's image and layout, comfort, and daily use of the building features.

3. Case studies and research methods

A previously developed BPE methodology (Gupta et al., 2019) developed for the Indian context (I-BPE), as part of a Newton Fund UK-India research project, was tested on two green buildings in the composite climate of India, as part of a postgraduate dissertation (by one co-author), with the intent to provide feedback on the relevance and effectiveness of the I-BPE methods as a research tool in the Indian context. A key aim of the case study is to better understand the challenges in applying the methods and tools of the I-BPE methodology, and how these might be improved to continue BPE studies in India.

The first case study building[1] (B1), a sustainable development research facility located in Gurgaon, India, is a LEED Platinum building completed in 2008. The building is constructed of heavy thermal mass with double glazed windows, and highly reflective roof surface and exterior paving materials to reduce heat gain. Shading devices reduce solar heat gain in the summer but permit solar gain in the winter. Internal courtyards provide natural light inside the building to reduce electrical lighting consumption throughout the year. The building also utilizes rain water harvesting, permeable paving, and waste water recycling for irrigation and toilets. During construction, excavated soil was used to make the bricks used in the building and renewable materials were used throughout. Table 2 lists important aspects for both case studies.

Table 2. Further building details

Detail	Building 1 (B1)	Building 2 (B2)
Green rating	LEED Platinum	LEED Platinum / GRIHA 5-star
Occupancy (typical)	150 occupants; Monday – Friday 8am – 6pm	900 occupants; Monday – Friday 9:30am – 5pm
Built-up area / Built-up area excluding unconditioned basement[A]	3,250m^2 / 2,660m^2	32,000m^2 / 19,130m^2
Programming/ form	Offices: ground, 1st and 2nd levels. Ground level: auditorium, reception, classrooms, conference room, cafeteria and kitchen. Basement: control room	Four wings around central courtyard; ground level plus seven stories and a basement. Offices, conference rooms, meeting rooms, a dining room, cafeteria, library and auditorium.
Cooling	AC	AC
Energy/ renewables	Electricity from grid; diesel generator backup; PV 58kWp, solar thermal	Electricity from grid; diesel generator backup; PV 930kWp
Fabric details (U-values)	Wall: 0.36 W/m^{2}K Roof: 0.35 W/m^{2}K	Wall: 0.37 W/m^{2}K Roof: 0.26 W/m^{2}K

[A]Used to calculate Energy performance Index (EPI), a normalization of energy consumption used for benchmarking in India represented as kWh/m^2/yr (BEE, 2017).

The second case study building (B2) is a GRIHA (Green Rating for Integrated Habitat Assessment) 5-star and LEED Platinum government office building in New Delhi, completed in 2014. The building is constructed of heavy thermal mass with double glazed windows. The roof is a terrace garden with extended photovoltaic (PV) panels to provide shade to areas of the roof and the upper stories. The exterior shell and all paving materials were also designed to reduce heat gain. Shading devices reduce solar heat gain in the summer but allow solar gain in the winter. Access to daylight was also designed to reduce electrical lighting consumption throughout the year. The building utilizes rain water harvesting and a

1 B1 is the first phase in a two-phase development of three buildings. Phase 1 comprised an office building and a guesthouse. Throughout the paper B1 will refer to the study of the phase 1 office building only; however, in the design phase, the guesthouse was included with the main office building for energy consumption simulation; therefore, the guesthouse is included in the energy analysis.

geothermal heat exchange system adopted for AC in the building, is contributing to the reduction in water consumption by eliminating the need for a cooling tower.

3.1. BPE field study methods

The field study was carried out for one month in the monsoon season (6 July – 13 August 2018). Due to the nature of student dissertations, there were limited resources and time. The primary components of the study included design and construction audit, energy audit, environmental audit and occupant survey. Table 3 shows the I-BPE recommend study elements divided in four levels of increased complexity. For each level, the table indicates the action taken and/or tools used. The review of design, fabric, and systems for both buildings included plans, simulation report, commissioning report, LEED credit report, interview with design team and facility manager (FM), and a walkthrough survey to observe design aspirations as they relate to reality of the occupied product. Though documentation was available, the review of installation and commissioning of systems was not performed due to student's limited knowledge.

Although the campus in which B1 is located is relatively data rich with submetering data available through a building management system (BMS), some submetering choices made analysis difficult. For example, the HVAC energy for both phase 1 & 2 buildings are metered through a single panel; however, the AC air handling unit (AHU) for B1 office building is metered separately. In addition, the design energy simulation breakdown of systems for consumption analysis did not match the metered panels in the building, making comparison challenging. B2 energy data were only available through energy bills as the BMS was not working at the time of study.

In B1, indoor environmental parameters, e.g. temperature, RH, CO_2 concentrations, etc. were successfully monitored; however, as B2 is a government building, they did not allow the installation of environmental loggers or photographs in workspaces. An occupant satisfaction survey (BUS) was conducted in both buildings to ascertain satisfaction with the work space and indoor environment. The BUS survey was distributed to regular occupants in B1 on 7 August 2018 and collected the next day. The response rate for B1 was high due the high level of interest from the owner in the process and survey findings. In B2, the BUS survey was distributed to regular occupants from 2-5 August 2018 due to the large number of occupants.

4. Results

4.1. Review of design intent: *B1*

The occupants, building owner and the management team were satisfied with the building design, facilities, image of the building, and fulfilment of their needs. These findings are also confirmed by the BUS survey. The FM received appropriate handover and operation manuals; however, as a non-technical person, the FM has established a good working relationship and communication with sub-contractors who are responsible for maintenance of the building.

All buildings on the campus were designed for mixed-mode operation. For the cool season, all spaces have operable windows. There is also the designed-in ability to night purge heat when nights are cool; however, there is no automated system for this. Furthermore, it was found that for reasons of security, dust, and insects, windows are rarely opened even when conditions are ideal. The temperature setpoint for the building is 26.5^{o}C. This is 0.5^{o}C below the Indian Society of Heating, Refrigerating and Air Conditioning Engineers (ISHRAE) (2016) maximum operative temperature threshold in summer for offices. In addition, all spaces have ceiling fans as it was anticipated that those who find the space too warm would turn on ceiling fans. The fans were in fact observed to be used in this way.

Table 3. Adaptation of the I-BPE methodology for this study *(NP = not performed)*

BPE study elements	Level 1	Level 2	Level 3	Level 4
Review of design intent	Collection and review of design docs.: *Drawings, occupancy details, applicable standards, and green bldg. cert. docs.*	Review of services and energy systems: *review of commissioning documents*	Interviews with key stakeholders: *Design team and FM*	Walkthrough with key stakeholders: *FM*
Technical building survey	Inspection of build quality and services: *with FM, photographic survey*	Controls interface survey: *limited review of lighting controls in B1 only*	Review of installation and commissioning of systems: *NP*	Thermographic assessment of building fabric: *NP*
Energy assessment	Annual / monthly energy data: *Monthly energy consumption, and PV generation (1 yr data)*	Energy monitoring: *NP*	Sub-metering: *B1 only: Access to daily energy use for all systems (lightning, power, etc.) through BMS*	Plug load monitoring of individual appliances: *NP*
Env. monitoring	Temperature and RH spot readings: *NP*	Temperature and RH monitoring: *B1 only: Hobo UX-100 reading temp. and RH (4 weeks at 5-min. freq.);* *I-button reading temp. (4 weeks at 5-min. freq.)*	Additional spot read/ logging (e.g. CO_2, lux, wind speed): *Watchdog measuring internal CO_2, environmental meter reading lux levels and noise.*	Additional pollutant measurement (e.g. PM, VOC): *B1 only: Foobot reading particulate matter (PM2.5) (μgm^3), CO_2 (ppm) and VOC (ppb) (4 weeks at 3-hr. freq.);* *Tinytag reading CO_2 (ppm) (2 weeks at 5-min. freq.)*
Occupant feedback	Occupant satisfaction survey: *B1: BUS (91 of 130 returned) (70%)* *B2: BUS (270 of 900 returned) (30%)*	Occupant interview: *NP*	Thermal sensation and preference survey: *B1 only: thermal comfort (TC) diary (37 of 130 returned) (28%)*	Focus group: *NP*

Note: darker shading indicates application in both buildings; lighter shade indicates only implemented in one building.

The open plan offices were designed with good acoustics; however, the BUS survey revealed noise from colleagues to be no better than expected, i.e. in line with the BUS benchmark. Despite the design of internal courtyards to help provide abundant natural light inside the building and thereby, reduce electrical lighting consumption, there were many instances where electrical lighting was left on where not needed. Furthermore, BUS survey results indicate there was enough natural and electrical lighting at the time of survey.

4.2. Review of design intent: *B2*

The occupants and the management team were satisfied with the building design, facilities, image of the building, and fulfilment of their needs. These findings are also confirmed by the BUS survey. However, many occupants complained about the furniture, space at their desk and storage. The FM did not receive proper handover and operation manuals and there has been a frequent turnover in FM position. This frequent change leading to little time to invest in the FM position could be a contributing factor to why the installed monitoring equipment and BMS remain offline and unrepaired since 2013. The green pavers, intended to reduce impervious, hardscaped surfaces has separated creating large gaps and safety concerns.

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4.3. Energy and indoor environment

The following energy analysis considers only energy data for the year covering 1 April 2017 – 31 March 2018. Overall, B1 is found to perform better than intended. There is almost no difference between the as-designed and as-built energy consumption for B1 (energy performance gap (EPG) of -0.3%); however, the renewable systems are not performing as intended resulting in an EPG of renewable systems of +9%. This raises the net EPG to +0.9%. B2 is performing relatively well also. The as-built energy consumption is below the as-designed prediction resulting in an EPG of -3%; however, B2 was designed to be a net-zero energy building. To achieve this, the building is highly dependent on the PV system to perform as intended. Unfortunately, the renewable system is not performing as intended, resulting in an EPG for the PV system of +19%. Table 4 shows the results for the as-designed and as-built energy consumption, generation and CO_2e emissions.

Energy performance evaluation limitations:

- The guesthouse was modelled together with B1 office building in design; therefore, the guesthouse is included in both as-designed and as-built results.
- B1 sub-metering designations did not match the simulated consumption for specified uses (e.g. lighting, HVAC), therefore, as-designed and as-built comparisons could not be made. As an example, in the simulation calculations the guesthouse energy requirements are combined with the main office building; however, the guesthouse is sub-metered as a single value.
- B1 was modelled for peak occupancy of 200 occupants per day. Though there is not a large difference in consumption this may contribute to the EPG.
- B1 energy predictions did not include the backup diesel generators in the model. The 5% of total annual energy used by diesel resulted in 4% less CO_2e emissions than modelled.

Table 4. Annual energy data for both buildings from 1 April 2017 – 31 March 2018

	Building 1 (B1)		Building 2 (B2)	
	As-designed	In-use	As-designed	In-use
Total energy use (kWh/yr)	378,266	377,310	1,400,000	1,356,615
Renewable generation (kWh/yr)	44,571	40,531	1,400,000	1,138,027
Net energy use (kWh/yr)	333,695	336,779	0	218,588
Net energy use/m^2 (kWh/m^2/yr)[A]	125.4	126.6	0	11.4
Net CO_2e emissions (kg/CO_2)[B]	273,630	265,243	0	153,958
Net CO_2e emissions/m^2 (kgCO_2/m^2/yr)	102.9	99.7	0	8.0

[A]Energy Performance Index (EPI)
[B]CO_2e emissions factors (kg/kWh): electricity=0.88 (Bhawan and Puram, 2014), diesel=0.267 (Ali et al., 2016)

Figure 1 shows the case study buildings' EPIs against relevant Indian benchmarks (Kumar et al., 2010, BEE, nd). Both buildings are performing better than the Indian Energy Conservation Building Code (ECBC) office building benchmark for the composite climate; however, B1 is not performing as well as some actual measured benchmarks of public sector buildings, though it is a LEED Platinum rated building.

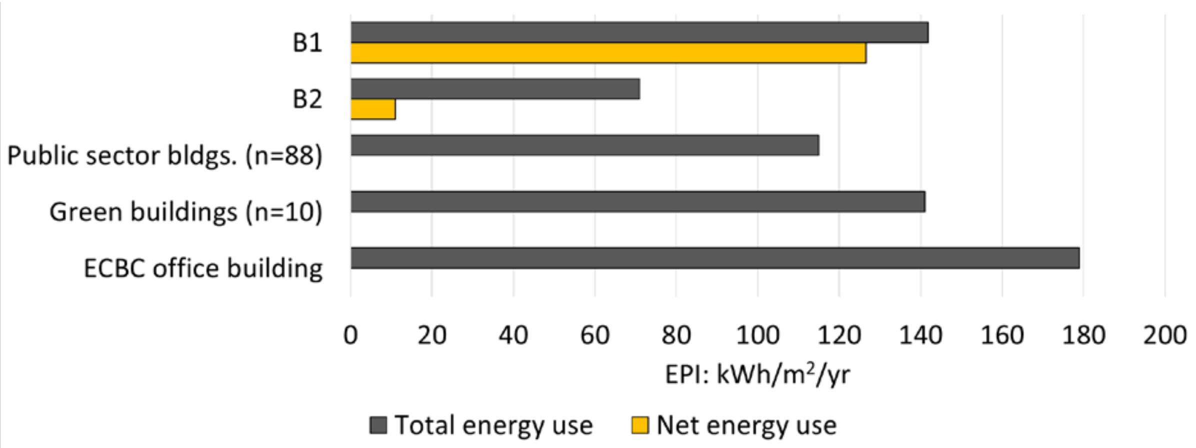

Figure 1. Annual energy data for both buildings and benchmarks from 1 April 2017 – 31 March 2018

Figure 2 shows the relationship between energy consumption and cooling degree days (CDD) (BizEE, 2019). Both buildings appear to have a strong correlation between respective energy consumption measurements used in the graph and CDD. Obviously, the relationship between AC AHU consumption and CDD for B1 is more helpful in understanding responsiveness to climate. This can be seen in the way that most months are close to the trendline except for September 2017. If September were removed the correlation would be r=0.91. To help compare like-for-like, total energy consumption correlation with CDD for B1 is r=0.82.

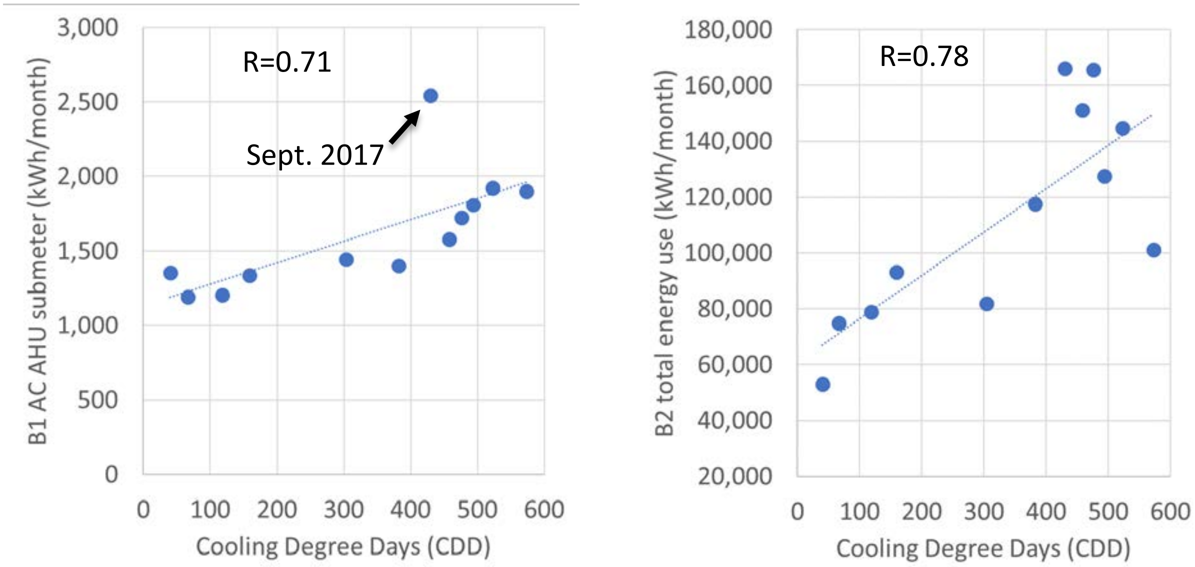

Figure 2. Energy & cooling degree day relationship 1 April 2017 – 31 March 2018 (B1 left/B2 right)

Unfortunately, as the B2 BMS system stopped monitoring environmental data and management would not allow data loggers to be installed in the building for the study, only the environmental data for B1 is reported. Figure 3 shows the maximum (max), mean, and minimum (min) temperatures and RH during occupied hours (in table 1) for one measured office on each floor, ground floor (GF) enclosed office, first floor (FF) open office, and second floor (SF) open office. The acceptable operative temperature range for offices in summer (24.5°C +/- 2.5) and RH according to the ISHRAE standard (ISHRAE, 2016) is shown with the gradient boxes. As operative temperature was not observed, dry bulb temperature is used here as a proxy. In the temperature graph, the setpoint is indicated by the yellow line. From this temperature graph, though there are maximums outside the recommend range, it appears that temperatures are remaining reasonably close to the setpoint and within recommended range. This is also true for RH; however, the average RH in the SF office is close to the max. This may indicate window opening behaviour. The lower temperature and RH in the GF office is likely indicating the enclosed nature; this is also more apparent in figure 4.

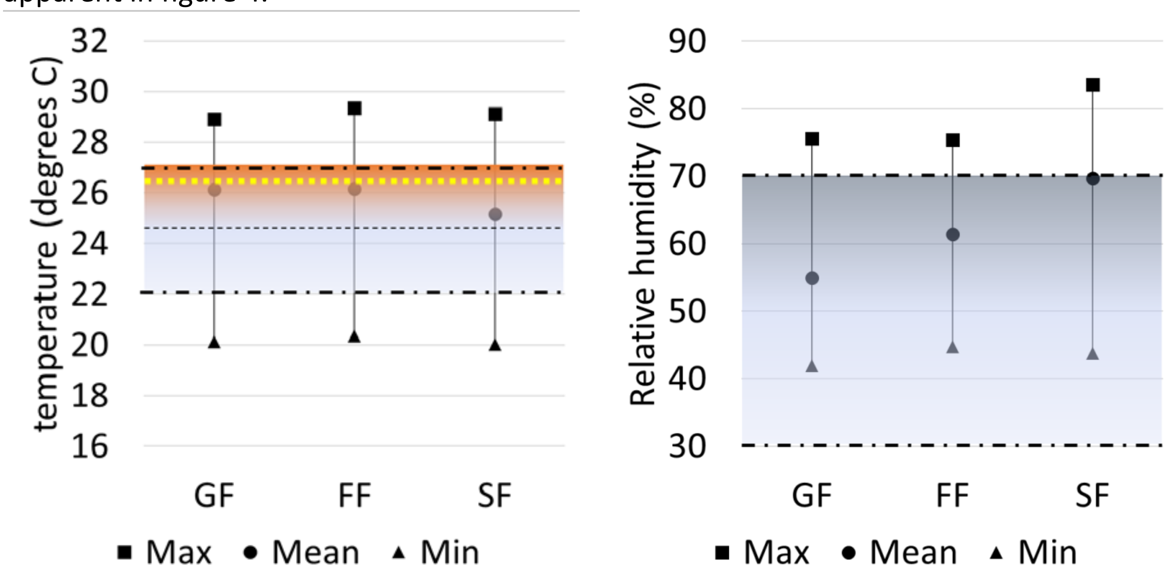

Figure 3. B1 office temperature and RH measurements, and recommended ranges for the period 6 July – 13 August 2018

Figure 4 shows the percent of occupied hours within (blue and yellow) and outside (red) of the acceptable temperature range. The same three offices are shown in the graph. Within these hours, it appears that there is a notable difference between the temperatures on each floor. On the ground floor only about 2% of occupied hours are above the threshold but on the first floor this is over 25% of occupied hours.

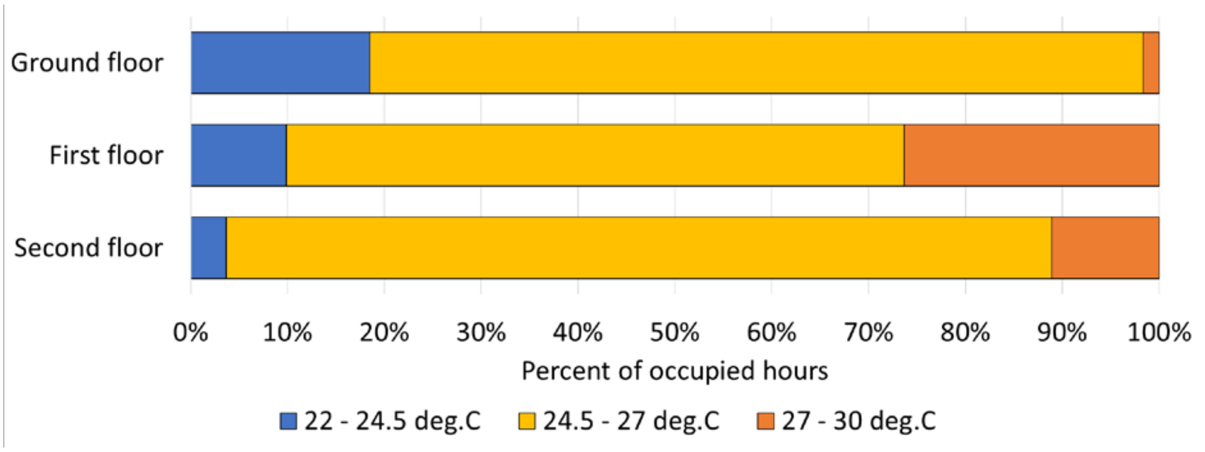

Figure 4. B1 office temperature measurements: percent of occupied hours at specific temperature ranges for the period 6 July – 13 August 2018

Figure 5 shows the indoor air quality measurements taken in the ground and second floor offices during the periods 18-25 July 2018 and 11-17 July 2018 respectively. ISHRAE (2016) thresholds are shown in the graphs for PM2.5 and CO_2. For these graphs the lower band indicates the Class A threshold: *aspirational* and the upper band indicates the Class C threshold: *marginally acceptable.* Mean PM2.5 concentrations in the SF office are above the ISHRAE Class C threshold but CO_2 is lower. As with higher RH, this may also indicate a higher frequency of window opening or access to open windows and cross-flow ventilation in the open plan SF office.

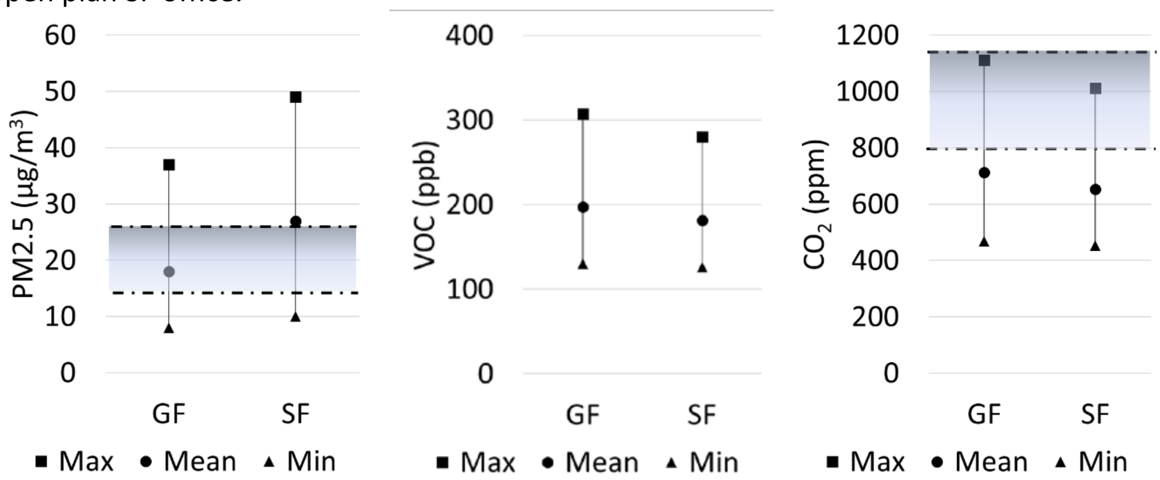

Figure 5. B1 GF and SF office IAQ measurements and ISHRAE standard thresholds

4.4. Occupant survey

According to BUS survey results, the design, the building's image to visitors, whether the building meets the user's needs and effectiveness of the use of the space of both buildings were all considered highly satisfactory in B1 and moderately satisfactory in B2. Overall lighting is considered satisfactory in the two buildings. In addition, the respondents in both buildings considered there to be enough natural light on the scale toward 'too much';

however, the mean response suggests there is little to no issue with glare in the buildings. Control over lighting in B1 is considered good and better than the BUS benchmark mean; the occupants in B2 appear to have less control, below the benchmark mean.

Overall comfort is rated moderately high in both buildings for both seasons; higher in B1. In both seasons the temperature is considered to be on the cooler side and the air is considered dry and still but also fresh and odourless for both buildings. Though comfort and temperatures are considered satisfactory, the respondents in both buildings consider control over heating, cooling and ventilation to be unsatisfactory. In both buildings productivity at work is perceived to have increased because of the environmental conditions in the building; furthermore, occupants feel healthier when in the building.

5. Discussion

In conducting the BPEs, between the two buildings, differences were found between between B1, a privately owned building wherein the owner showed great interest in conducting building performance evaluation study whereas in B2, a government building had high levels of restriction and continual barriers and permissions to seek.

Many people in both the buildings were not able to understand questions in the BUS survey. Much time was required from the evaluator to explain the meaning of questions. For this reason, it is recommended that the BUS questionnaire be modified and tested for the Indian context to simplify language and/or translate the forms. Many occupants simply refused to take the BUS survey and TC diary. People are generally busy, especially in a workplace environment; for a higher rate of return an incentive would be ideal. The TC diary is not recommended in its current paper form. It was difficult to get occupants to fill the long and monotonous TC diary. People didn't find it interesting to fill which led to missing blanks, day skipping, and a low response rate. A reminder from the management team in B1 to each occupant was set three times a day but this was only possible provided the interest of the owner in the project. Though again this may require an incentive, especially to install an application on an individual's smart phone, but TC diaries would be less difficult to complete if it were app-based with notifications to prompt simple quick responses.

Regarding the energy consumption of the buildings, the current EPG is considered reasonably acceptable as some variation in both predictions and measurements due to the realities of uncertainties (inherent in predictions) and data scatter (inherent in measurements) should be allowed (De Wilde, 2014). Furthermore, as these buildings are performing better than intended, it would not be desirable to increase energy consumption to meet design predictions. The simulation methods and the installed efficiencies of the PV systems should be reviewed to understand where the EPG is most affected to avoid repeat results. Though the EPG is far worse for B2 it is performing exceptionally well as compared to the benchmarks and as compared to B1, also a LEED Platinum rated building. B1 is not performing as well as certain benchmarks; therefore, it brings into question what should be expected considering the energy performance of LEED Platinum buildings. In the certification process, there are many credit paths to achieve this certification level; however, a certain level of energy performance would preferably be inherent. That is, for example, a LEED Platinum building should be guaranteed to have a lower EPI than Gold which is not always the case (Sabapathy et al., 2010).

6. Conclusion

This study shows the process of testing the I-BPE methodology on two LEED Platinum office buildings in the composite climate of India. The field study was carried out for roughly 30 days which included data monitoring, walkthroughs and occupant surveys. The field study offers a template for replication of BPE and benchmarking data for green buildings in India. The next step in the Learn-BPE project involves testing the I-BPE approach on several other case studies implemented by students using a programme developed for this purpose. The I-BPE case studies intend to demonstrate actual performance of certified green buildings in India, publish the data, and continually provide a testing platform for refinement of the I-BPE framework for application in India. Finally, the I-BPE case studies are also intended to build trust in the Indian building industry, which is currently shy of exposing itself to liability risk resulting from actual building performance

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