Building Envelope Retrofitting Strategies for Energy-Efficient Healthcare Architecture in India

Zeeshan Ahmad Ansari, Purva Mujumdar, Tejwant Singh Brar, Mohammad Arif Kamal*

Sushant School of Art & Architecture, Sushant University, Gurugram, India

* Corresponding Author: architectarif@gmail.com

Abstract: Building a developing economy like India requires energy conservation and efficiency. India continues to produce and consume a lot of energy, with the business sector responsible for 21% of this total. The energy consumption of hospitals in India is expected to increase by 12–15%, hence this demand would only increase. As a result, energy retrofitting is urgently needed. The purpose of this research is to assess the many retrofitting alternatives that might be applied to the building exterior from an architectural perspective. Double-glazing windows, roof insulation, and wall insulation are among the insights that will be incorporated into the retrofitting approach. The Energy Performance Index is used to assess the hospital's energy usage, after which all possible retrofit alternatives are taken into account. All of the measures that would close the gaps found during the evaluation are included in the simulation model created for the hospital building selected for the case study. The energy consumption of each retrofit measure is then computed. The Trauma Center's new hospital building at Jawaharlal Nehru Medical College in Aligarh has been chosen for the investigation. In order to achieve the best outcome for the chosen building, an assessment of a range of retrofitting methods in this paper was examined, including passive architectural interventions, active technological interventions, or a mix of both. The retrofitting strategies shall turn out to be an energy-efficient solution, according to the findings.

Keywords: energy retrofit, building envelope, energy performance index (EPI), energy conservation, healthcare architecture, India

1. Introduction

The emissions of carbon dioxide have a big effect on the environment and are a big part of the issues surrounding global warming. CO_2 is the biggest environmental hazard in the building and construction sector. In order to counteract the greenhouse gases that are destroying the ozone layer, this has spurred research into creating new building systems and technologies. The windows, where heat gain and loss occur and solar radiation immediately enters the structure, are the most vulnerable part of the building envelope. (Bangre et al., 2023).With one of the world's fastest-growing economies, India uses and produces a significant amount of energy. There are various aspects to keeping the economy in the best possible shape. The two main elements that are crucial to the development of the economy are energy efficiency and conservation. It is imperative that the energy efficiency process be accelerated. Other issues are brought on by the nation's exceptionally hot heat, particularly with regard to the energy expenses associated with the cooling of buildings. At the moment, buildings account for roughly 35% of all energy production, whereas the business sector uses 9% of all energy (Evans, 2015). Since the healthcare sector operates around the clock, it is the sector with the highest energy usage (Chakraborty, 2020). Hospital buildings in India have grown at a rate of 12–15% over the past ten years, and they account for 2-3% of the country's overall energy consumption.

The World Health Organization predicts that India needs 80,000 extra capacities annually to handle its expanding population (Teja et al., 2016). The World Health Organization has urged all healthcare facilities to implement climate change mitigation techniques immediately. As the healthcare industry works to reinvent itself, the widespread perception of it as a massive waste of water, energy, and other resources is shifting. As an alternative to the traditional hospital and healthcare facility designs, the idea of "green healthcare design" is becoming more and more popular. To improve energy security and lower greenhouse gas emissions in a developing nation like India, energy-efficient retrofitting of existing hospitals is required. Retrofitting the envelope of the old buildings, rather than focusing solely on the designs of the new structures, is necessary to address the issue of energy efficiency while preserving the greatest possible living circumstances for patients (Dandia, 2021).

Destroying and rebuilding converted hospitals is a difficult task for sustainability. Among the measures used to enhance healthcare buildings' energy consumption performance are renovation, retrofit, and refurbishment. The distinct usage patterns and upgrade potential of a project must be thoroughly analyzed and assessed in order to develop an effective retrofit scope. Load reduction, efficient use of ambient energy sources, efficient equipment use, and efficient control strategies are all examples of energy-efficient design techniques. To ensure that engineering systems and architectural aspects work together effectively, an integrated design approach is required. However, the majority of energy-efficient retrofit projects currently concentrate primarily on engineering considerations.Retrofitting strategies can improve energy usage and reduce energy demand (Pan, 2007). The government has concentrated on creating strategies to lower greenhouse gas emissions ever since the Kyoto Protocol was signed (Communities, 2009). The recent progress in the alternative sources of renewable energy is the most effective way to combat these massive energy emissions and satisfy the demand for energy consumption around the world (Reddy, 2021). Since most hospitals are constructed using the same basic design, hospitals have a lot of potential to save energy, according to a 2012 Press Information Bureau (PIB) report. As a result, creating a retrofit strategy that can be implemented in multiple hospitals is simpler. However, implementing this plan is difficult and calls for strategic excellence (Chakraborty, 2020). The most efficient and pertinent ways to accomplish this are through the use of building simulation models or BIM.

2. Literature Review

Despite positioning itself as an advocate for public health and well-being, the healthcare industry has been a significant contributor to environmental deterioration, which gave rise to the idea of "green" healthcare. "Green" healthcare tries to reduce potential environmental impact from medical procedures while also preserving and improving human health. Technological developments, environmental movements, and international initiatives to promote sustainability have all had a significant impact on its evolution. Due to increased awareness of the threats posed by climate change, the concept of "green healthcare" has begun to gain traction in recent years. Since climate change has both direct and indirect consequences on health, the public health sector has come to be considered as having a responsibility to mitigate its effects. Hospitals and healthcare systems started implementing measures that were essential to the mitigation strategy, such cutting greenhouse gas emissions and utilizing renewable energy sources. There is growing acknowledgment that green healthcare is necessary since healthcare systems around the world are major pollutants, and sustainable development cannot be discussed without them (Ahmad et al., 2025).

India uses and produces a significant amount of energy. There are various aspects to keeping the economy in the best possible shape. The two main elements that are crucial to the development of the economy are energy efficiency and conservation (Kamal & Ahmed, 2023). Accelerating the energy efficiency process is essential. Using energy remodeling techniques is one of the greatest ways to overcome low building energy efficiency (Grillone, 2020). There is a 20–50% probability of saving energy for power end users including ventilation, cooling, and lighting, according to numerous case studies of energy audits in Indian hospitals and business buildings (USAID, 2009). Numerous research have been conducted to quantify ways to lower building energy usage, including orientation, glass coating, air conditioning management, sunlight, roof insulation, and more (Florides, 2022).

Given the energy intensity of healthcare systems, cutting carbon emissions is one of the main advantages of green healthcare. Hospitals use a lot of energy, mostly from nonrenewable sources, for equipment operation, heating, ventilation, and lighting. Using retrofitting strategies and clean energy sources like solar photovoltaic can help healthcare architecture drastically reduce their carbon emissions. Renovating the building is the best way to lower greenhouse gas emissions and electricity consumption (Mona, 2021). There are many building retrofit solutions on the market now that are easily accessible. The choice of retrofit technology (or measure) for a given project is a multi-objective optimization problem, though, and is influenced by a number of factors, including the building's specific characteristics, the overall budget, the project's goal, the types and efficiency of the building services, the building fabric, etc. The retrofit efforts result in a 39% reduction in the consumption of the building energy (Alazazmeh, 2021). Reducing energy loss, especially through the building envelope, can lower building energy usage (Kamel, 2022). Kamal and Bano investigated how the building envelope affected energy efficiency in Indian office buildings and offered solutions to lower office energy costs (Kamal & Bano, 2016). According to Ardente et al. (2011), the enhancement of glazing, illumination, and envelope thermal insulations were the three main advantages of energy consumption evaluation. The study's methodology consists of evaluating the selected buildings, comparing them to the standards, and looking into potential building envelope-focused retrofitting alternatives. The simulation tool Rhino 7 with Climate Studio is then used to create a prospective model of the selected building, implying the possible possibilities.

3. Research Methodology

The Trauma Center at JNMC, in Aligarh has been selected for the thorough examination and investigation for the retrofitting strategies in this study. We must learn about energy-efficient retrofit techniques through a review of the literature and real-world examples. The selected case study is then subjected to the conclusions drawn from the analysis. Studying and putting into practice retrofit methods at the Trauma Center in Aligarh, India, was the aim. To better understand different features, architectural and operational characteristics, occupant concerns, and building usage, we first carried out a pre-retrofit survey. Three techniques were employed during the pre-retrofit assessment to get insight into the building's actual usage pattern: design analysis based on the technical data and drawings supplied, on-site physical inspection. The Trauma Center building is situated in Aligarh, India. The built-up space is approximately 6892 m^2, and the area of the ground floor is 2327 m^2. It is a three-storied building G+2. The outer wall is 230 mm thick using clay brick and has both sides plaster, U-value is 2.13 W/m^2K, and the roof is a flat concrete slab with thick brick tilling over it (U-value is 2.07 W/m^2K). Windowsare6mmthick single glass and have aluminum frame (U-valueis 7.1W/m^2K).

3.1 Energy Evaluation

Using Rhino 7 and Climate Studio 1.9, create a simulation model with the present building specs as the initial stage in this process. The hospital's Energy Performance Index that is EPI, is then determined using this model. A useful instrument for monitoring and comparing building energy consumption performance is the Energy Performance Index (EPI). Since energy consumption is determined by the overall floor area, EPI is correlated with building size (Bakar, 2015).

3.2 Retrofitting Options

Numerous retrofit solutions are identified for various characteristics, such as the building's external wall and window roof. Adding thermal insulation to external walls and roofs is one possible alternative; ETICS, an external thermal insulation composite panel with a U-value of 252 W/m^2K, is utilized for this purpose. All windows should be replaced with double low E 3mm, 13mm air gap windows with a U-value of 1.53W/m^2K and more projection added to the windows. These inputs are used to build simulation models, which are then compared to determine which one offers the most energy efficiency.

4. Findings and Discussion

4.1 Basecase

A model as a base case has been prepared for simulation with the specification given as below:

The outside wall has a U-value of 2.13 W/m^2K and is 230 mm thick, made of clay brick with plaster on both sides.

The roof has a U-value of 2.07 W/m^2K and is made of thick brick tilling over a flat concrete slab.

Windows have an aluminum frame and a single glass that is 6 mm thick (U-value: 7.1 W/m^2K).

The results of the simulation have been shown in Figure 1. The enrgy performnace index EPI for the base case is 289 KWh/m^2/Yr.

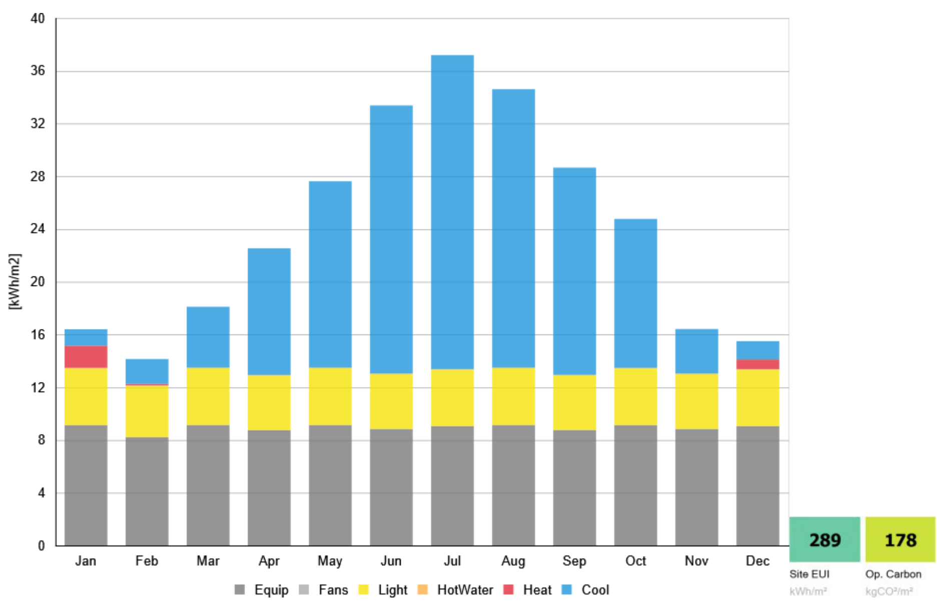

Figure 1. Energy Performance Index (EPI) for the Trauma Centre

4.2 Roof Insulation

The Polyurethane spray of thickness of 30mm and density of 42 ±2 kg/m^3 (having U-value is 0.579 W/m^{2}K) has been applied. The results of the simulation as shown in Figure 2, the Energy Performance Index (EPI) is 272 KWh/m^2/Yr.

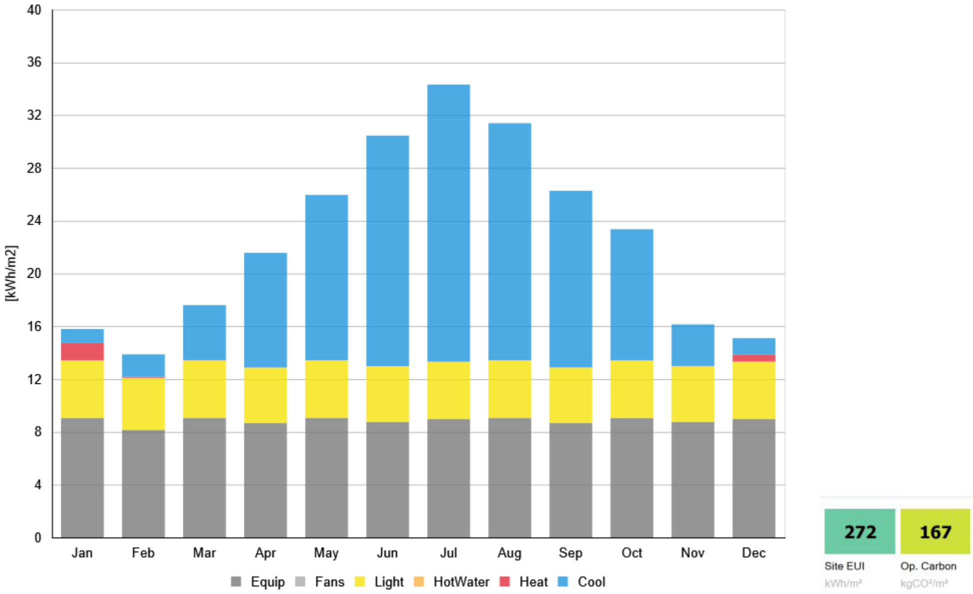

Figure 2. Energy Performance Index (EPI) for Trauma Centre with roof insulation

4.3 Replacing Windows

According to the results of simulation as shown in Figure 3, the EPI for this example is 271 KWh/m^2/Yr. The Double Glazing 13mm air Gap windows (U-value 0.579 W/m^{2}K) are substituted with the existing windows in the basic model.

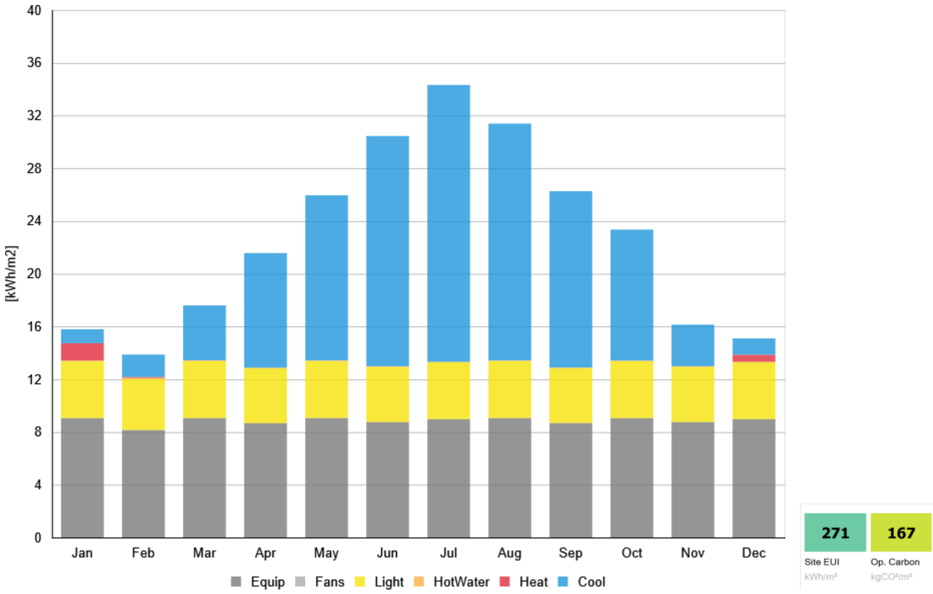

Figure 3. EPI for Trauma Centre with roof insulation + replacing windows

4.4 Insulation on the Exterior of Wall

In the base model, the exterior wall is constructed using the External Thermal Insulation Composite System ETICS (U-value = 0.252 W/m^{2}K); according to the simulation results as shown in Figure 4, the EPI for this instance is 215KWh/m^2/Yr. The EPI savings after utilizing every retrofitting fitting option covered in this research is 74 KWh/m^2/Yr.

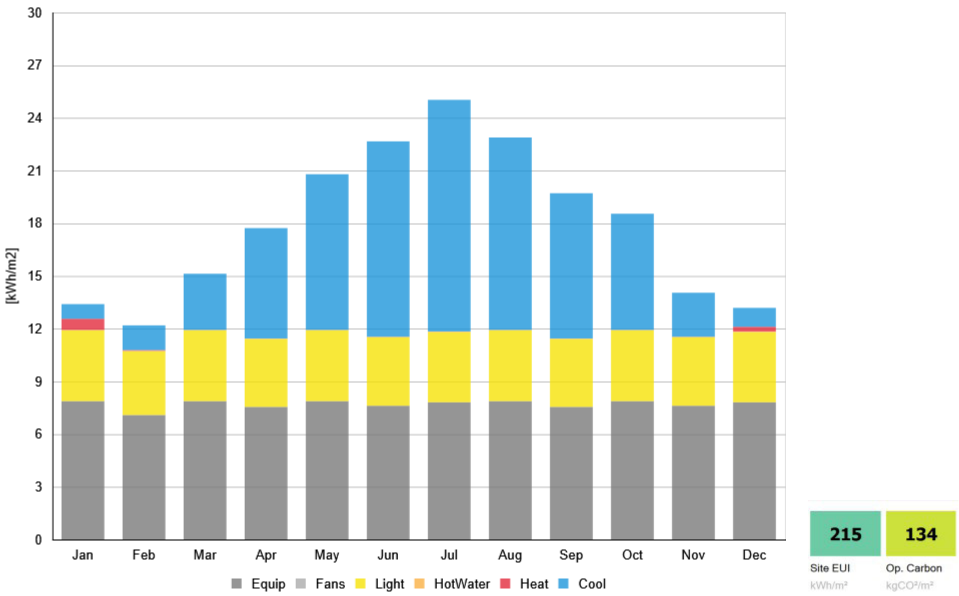

Figure 4. EPI for Trauma Centre with roof insulation + replacing windows + outer wall insulation

5. Conclusions

The effect of improving building envelopes on energy consumption in hospital buildings was examined in the setting of Aligarh, India's composite climate. The study examined the building's actual energy performance using site observations and monthly energy consumption data gathered from utility bills. This study focuses on green healthcare design in India, which refers to the use of environmentally friendly building and operating techniques in this field. The study sheds light on the necessity of balancing the goals of environmental sustainability and the health care system, especially for India. Other nations who are about to implement sustainable methods in their health systems can benefit from the information provided by this study, which has ramifications beyond India. This enables India to set an example for other countries, by demonstrating how health care system reforms may be implemented to address present demands without forgoing long-term expenditures in creating sustainable foundations. According to the study, greening healthcare facilities improves environmental quality, fosters social welfare, and lowers the carbon footprint of healthcare operations, and benefits patients and the standard of treatment provided. How to provide sustainable healthcare without sacrificing the nation's environmental vision was the main research subject. Although India has not yet completely developed the notion of green healthcare, it has made notable progress in incorporating sustainable techniques into hospital operations and architectural design.

Both active and passive approaches must be taken into account and assessed in order to create the best possible energy-efficient retrofit plan. The thorough examination of several energy-efficient retrofit options related to the case study shows that, given the financial perspective and ease of installation, choosing challenging and costly options that might become impractical is not always necessary to get the best results. Additionally, in order to analyze different passive design strategies like thermal insulation, glazing type, and shading devices, as well as combinations of different retrofitting strategies, simulations are conducted for both the original models and the models modified with each potential strategy separately. When it comes to energy conservation, wall insulation works best. Since the Window Wall Ratio (WWR) is less than 25% in this case, replacing double-glazed windows is not a wise retrofit option. It could be wiser to replace windows if the WWR is greater than 50%. When compared to the insulation in the outer wall, terracing insulation appears to save energy, but it is ineffective. Without a doubt, these building retrofitting solutions will reduce the environmental problems caused by excessive energy and other resource use and our need on artificial means for thermal comfort. As a result, a more climate-responsive, sustainable, and environmentally friendly built form will emerge in the future (Kamal, 2012).

References

[1] Ahmad S., Verma T., Arif Kamal M. (2025), Emerging Trends in Green Healthcare Building Design of Saudi Arabia: a Sustainable Approach, Russian Journal of Building Construction and Architecture 66(2).

[2] Alazazmeh A., Asif M. (2021). Commercial building retrofitting: Assessment of improvements in energy performance

and indoor air quality Case Studies in Thermal Engineering. DOI: 10.1016/j.csit.2021.100946
[3] Ardente F. (2011). Energy and environmental benefits in public buildings as a result of retrofitactions. Renew. Sustain. Energy Rev.15(1),460-470.
[4] Bakar N. N. A., Hassan M. Y., Abdullah H., Rahman H. A., Abdullah, M. P., Hussin F. and Bandi, M. (2015). Energy efficiency index as an indicator for measuring building energy performance: A review. Renewable and Sustainable Energy Reviews, 44, 1-11.
[5] Bangre A, Surwade R., and Kamal Arif M. (2023). Prospects of Double Glazed Windows in Buildings: Energy Conservation and Environmental Sustainability, American Journal of Civil Engineering and Architecture, 11(3), 64-69.
[6] Chakraborty, I., Banerjee S. and Mehndi M. S. (2020). Guidelines for the Design of Energy Efficient Retrofitting Strategies using BIM in Multispeciality Hospitals: Case Study Uttar Pradesh India. Pramana Research Journal, 10(8), 88.
[7] Dandia G., Pratheek S. and Chaitali B. (2021). Evaluation of Energy-Efficient Retrofit Potential For Government Offices In India. Architecture and Engineering, 6(2), 3-17.
[8] Evans M., Yu S. A. and Delgado A. (2015). Building Energy Efficiency in India: Compliance Evaluation of Energy Conservation Building Code. Energy Efficiency of Buildings in India and China, Analysis and Activities. DOI: 10.2172/1128633
[9] Florides, G. A. (2022) Measures used to lower building energy consumption and their cost effectiveness, Brunel University, Uxbridge Publications, 523.
[10] Grillone B., Danov S., Sumper A., Cipriano J. and Mor, G. (2020). A review of deterministic and data-driven methods to quantify energy efficiency savings and to predict retrofitting scenarios in buildings. Renewable and Sustainable Energy Review.
[11] Kamal Arif M. & Ahmad E. (2023). Analyzing Energy Efficient Design Strategies in High-rise Buildings with Reference to HVAC System, Architecture Engineering and Science, 4(3), pp. 183-196.
[12] Kamal Arif M. and Bano F., (2016). Examining the Role of Building Envelope for Energy Efficiency in Office Buildings in India, Architecture Research, 6(5), 107- 115.
[13] Kamal Arif M. (2012). Reinventing traditional system for sustainable built environment: An overview of Passive Downdraft Evaporative Cooling (PDEC) technique for energy conservation, Journal of Research in Architecture and Planning, 11(2), 56-62.
[14] Kamel E. and Memari A. M. (2022). Residential Building Envelope Energy Retrofit Methods, Simulation Tools, and Example Projects: A Review of the Literature. Buildings, 12, 954. DOI: 10.3390/buildings1207095
[15] Monna P. S., Juaidi A., Abdallah R. and Albatayneh A., Dutournie P. and Jeguirim M. (2021). Toward Sustainable Energy Retrofitting, a Simulation for Potential Energy Use Reduction in Residential Buildings in Palestine.12th International Renewable Engineering Conference (IREC).
[16] Pan Y., Huang Z. and Wu G. (2007). Calibrated building energy simulation and its application in a high-rise commercial building in Shanghai. Energy and buildings, 39(6), 651-657.
[17] Reddy C. R., Goud B. S. Rakesh T. Rajesh N., Reddy B. N. and Aymen F. (2021). Grid Integration of Renewable Energy Sources using GA Technique for Improving Power Quality. International Journal of Renewable Energy Research, 11(3), 1390-1402.
[18] Teja L. R., Singh V. K., Gomes A. P. F. (2016). Quantitative Assessment of Advanced Energy Efficiency Retrofitting for Hospitals in India. Proceedings of the ASME 2016 10th International Conference on Energy Sustainability ES2016, 26-30 June 2016, Charlotte, North Carolina.
[19] USAID ECO-III Project. (2011). Energy Use in Commercial Buildings - Key findings from the the national benchmarking study. USAID-India.