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Assessment of Building Energy Performance for EEMs – A Case Study in Mumbai

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Abstract

This study shows the energy conservation potential in a proposed office building situated in Mumbai, which is under warm and humid climate zone of India. The study also shows the savings in energy consumption and payback for selected types of energy efficiency measures. In this study, selected energy efficiency measures related to building envelop, HVAC and lighting systems were taken into consideration for energy conservation, to get the impact of each energy efficiency measure on energy consumption. Different operational and design related measures of HVAC systems have been studied using eQUEST-3.63b software to investigate the proposed design and operational measures for reducing energy consumption in similar type of commercial buildings.

Key words: commercial building; energy efficiency; energy conservation measures; building energy performance, building energy modeling and simulation.

1. Introduction

The energy use for industrial and commercial purpose in India is about 28%, which needs to be reduced substantially therefore it provides a motivation for improving the energy performance of industrial and commercial purpose. This is a significant opportunity and has a strong potential for the researcher to undergo in depth assessment of building energy performance for the commercial building. The objective of this study was to investigate the impacts of building envelop, HVAC and lighting design parameters on energy efficiency in the proposed commercial buildings situated in warm and humid climate zone of India and to perform cost benefit analysis on selected energy efficiency measures.

2. Building Information

This multi-storey building was an office building, which was a nine storey commercial building located in Mumbai at 18° 58’ towards North and 72° 50’ towards East. Gross floor area and conditioned area of the building were 323634 ft^2 and 173070 ft^2 respectively. The designed maximum occupancy of the facility was 1080. The floor to floor height was varying from 11.5 to 13.5 ft.

3. Building Energy Modeling and Simulation

Building energy modeling and simulation has being done in eQUEST-3.63b software. The eQUEST-3.63b is a whole building energy simulation tool which allows a graphical display of 3D geometry to describe the building. As per the views shown in figure 2, the building has been modeled to evaluate the energy use and the energy efficiency performance of the building. One base model of the facility with all the required parameters was constructed in eQUEST-3.63b. The facility was divided into different thermal zones. A typical zoning plan developed for ground floor is shown in figure 1. Each zone was assigned properties such as LPD, EPD, occupancy, floor-to-floor height, material conductivity & fenestration area etc.

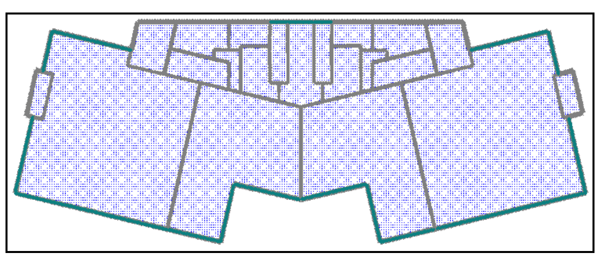

Figure 1. 2D View of the model

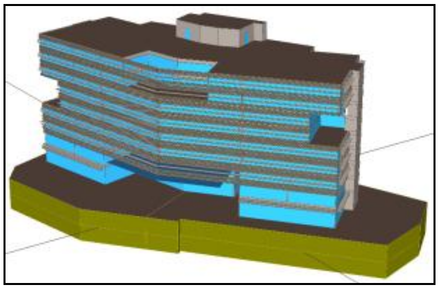

Figure 2. 3D View of the model

4. Building Systems

The exterior walls of the building were designed as 230 mm normal brick wall with 20 mm plaster on both sides. The roof was configured from outer to inner as 25 mm thick China mosaic tiles, 15 mm thick Brickbat coba, 150 mm thick RCC slab and inside plaster layer of 20 mm. The façade glass was 6 mm thick single glazed unit (SGU) having overall heat transfer coefficient (U-value) as 0.968, shading coefficient (SC) as 0.59 and solar heat gain coefficient (SGHC) as 0.51. The overall window to wall ratio (WWR) was 52%. The building's HVAC water side system was designed with 2 water cooled screw chillers. The chillers equipment capacity was 517 TR each. The air side system was designed 43 constant air volume (CAV) air handling units (AHU) serving the different zones of the building. The cooling of the building was provided by chilled water from the plant. Chillers were rejecting heat in open cooling tower having constant speed fans. Water side of HVAC system has primary and secondary chilled water pumping system. The primary and secondary chilled water pumps as well as condenser water pumps were constant speed pumps. Fluorescent lamps and T5 lights were designed for interior as well as exterior illumination. The elevator load in the facility was 51 kW.

5. Energy Consumption

In-order to assess the energy performance and to evaluate the relative consumption of the selected building, energy consumption breakdown of the building has been studied. The energy modeling and simulation results of the baseline building have provide comprehensive records of all energy consumption breakdown of the facility.

The study has elaborated the base case energy simulation results for the commercial building in figure 3. The energy simulation results of the building has represented that the energy use in air-conditioning (space cooling) was 9%, ventilation fan 33%, area light 9% and pumps 5%. This constitutes around 56% of the building's total energy consumption. Hence, the researcher has targeted these areas to reduce the energy consumption. As shown in figure 3 remaining 22% energy has been consumed by the miscellaneous equipments such as building's office, restrooms and kitchen equipments, elevators and lifts. The energy consumption breakdown of the facility after implementing proposed EEMs has given in figure 4 which represents that the energy consumption has been reduced significantly after implementing the EEMs. Space cooling and ventilation fan energy consumption reduce after improving the building's enveloping parameters, use of energy efficient low EIR chillers, VFD on AHUs and AHU SAT reset control. Pump energy consumption reduces after implementing VFD control on SCHW pumps and CHW supply temperature reset control. Energy consumption in heat rejection reduces after implementing VFD control on cooling tower fans and area lighting energy consumption reduces after using reduced LPD for basements and car parking.

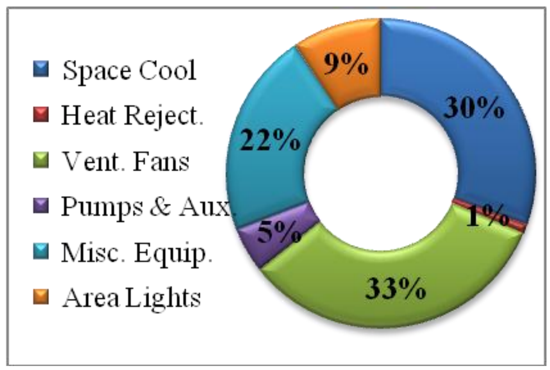

Figure 3. Base case energy consumption

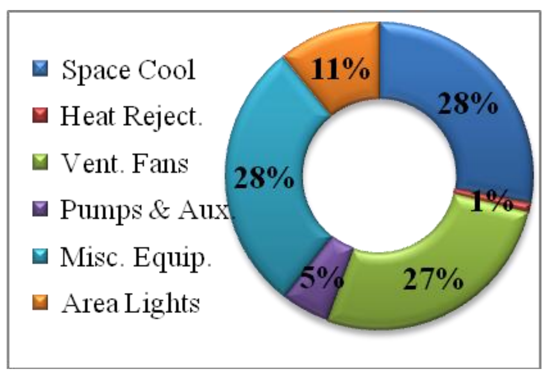

Figure 4. EEMs energy consumption

6. Energy Efficiency Measures (EEMs)

The researcher has implemented the following energy efficiency measures in a sequence which has lead to conservation of energy and energy saving. The EEMs have been analyzed for systematic assessment of building energy performance in the commercial facility:

EEM-01. **Insulated Wall:** 26 mm XPS insulation provided in the exterior walls. The U-value of the wall became as 0.123 Btu/hr ft^2 °F.

EEM-02. **Insulated Roof:** Over-deck extruded polystyrene (XPS) insulation of 60 mm has been provided. The U-value of the insulated roof became 0.0633 Btu/hr. ft^2 °F.

EEM-03. **Efficient Glazing System:** The SGU has been replaced with DGU having U-value = 0.56 Btu/hr ft^2 °F, SF/ SHGC = 0.25 and SC = 0.29.

EEM-04. **Energy Efficient Chillers:** The chillers of COP 5.4 has been replaced with COP 6.1 (EIR = 0.1639).

EEM-05. **VFD Control on Secondary Chilled Water Pumps:** The secondary chilled water pumps were made equipped with VFD.

EEM-06. **Air Handling Unit Fan VFD Control: T**he constant speed AHU fan motor has been equipped and controlled by VFD.

EEM-07. **VFD Control on Cooling Tower Fans:** The cooling tower fan motors has been equipped and controlled by VFD.

EEM-08. **Supply Air Temperature Reset:** The SAT reset technique was employed to reset the SAT supply temperature upward on a reduction in SAT load i.e. lower ambient temperature as follows:

Outside Air Temperature	Supply Air Temperature Set Point
60 °F	55 °F
82 °F	70 °F

EEM-09. **Chilled Water Supply Temperature Reset:** The CHWST reset technique was employed to reset the chilled water supply temperature upward on a reduction in chilled water load i.e. lower ambient temperature as follows:

Outside Air Temperature	Chilled Water Supply Set Point
60 °F	54 °F
82 °F	44 °F

EEM-10. **Car Parking Lower Lighting Power Density:** The LPD for car parking was reduced from 0.5 W/ft^2 to 0.15 W/ft^2 having lux around 100-150.

7. Energy Consumption Analysis Results

The results of energy consumption analysis has been tabulated in table 1, which shows that an overall energy savings of 2124255 kWh, which was 24.91% over base case has been achieved by combined effect of energy efficiency measures under study.

Table 1. Energy consumption analysis results

Base Case / EEMs	Energy Consumption (kWh)	Energy Consumption (kWh/ft^2year)	Energy Savings (kWh)	Energy Savings (kWh/ft^2year)	% Savings over Base Case
Base Case	8526395	26.346	NA	NA	NA
EEM-01	8488222	26.228	38173	0.118	0.45
EEM-02	8434852	26.063	91543	0.283	1.07
EEM-03	8175667	25.262	350728	1.084	4.11
EEM-04	8230496	25.432	295899	0.914	3.47
EEM-05	8502817	26.273	23578	0.073	0.28
EEM-06	7348970	22.708	1177425	3.638	13.81
EEM-07	8517895	26.320	8500	0.026	0.10
EEM-08	8506411	26.284	19984	0.062	0.23
EEM-09	8519385	26.324	7010	0.022	0.08
EEM-10	8414980	26.002	111415	0.344	1.31
		Total =	**2124255**	**6.564**	**24.91**

8. Evaluation of EEMs

The savings in annual energy consumption by EEMs over the base case for the building has been shown in figure 5. The graph reveals that percentage of energy savings has been varying in the building because of EEMs characteristics in terms of building envelop, HVAC systems, lighting systems, their different equipment capacities or technical specifications of HVAC air and water side systems etc.

The figure 5 revealed that the maximum savings has been achieved through VFD control on AHUs 13.81% and by efficient glazing system 4.11% out of total savings obtained in this facility of 24.91%. It has been also noticed that least savings of 0.08% has been found by applying reset control on chilled water supply temperature, which is a low investment EEM. The overall savings of 24.91% has shown good results by combined performance of all energy efficiency measures together. The figure 6 shows the effect of monthly energy consumption by combined performance of energy efficiency measures over the base case.

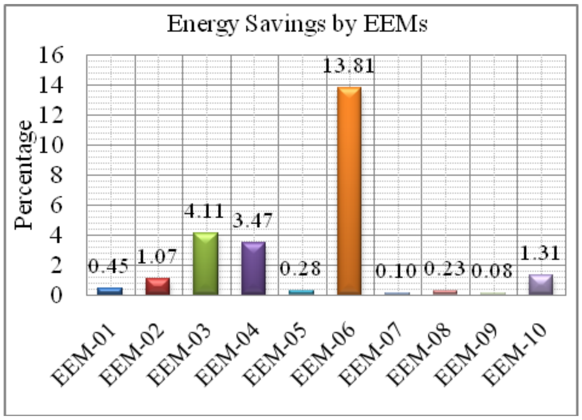

Figure 5. Comparison of savings in annual energy consumption by EEMs

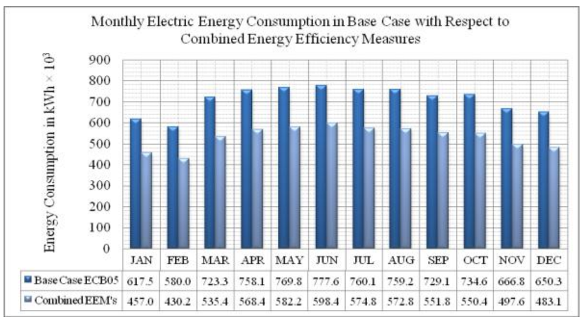

Figure 6. Effect on monthly energy consumption by combined EEMs

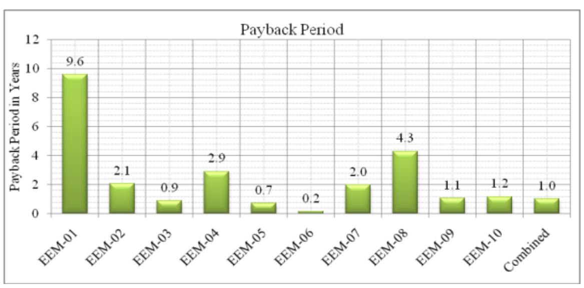

Figure 7. Effect on payback period by different EEMs

The figure 7 has shown that the payback period for the various EEM investigated which has been in the range from 0.2 to 9.6 years. While the combined payback period of all the EEMs for this commercial facility was found 1 year. The EEM-01 has shown extreme result which would be resulted due to less energy saving with respect to high capital cost of implementation; hence the payback potential have been reduced. The energy savings by this EEM was 0.45% only. On the basis of the evaluation of annual energy use pattern of the building, all proposed energy efficiency measures for the building were analyzed. The EEMs categorized on the basis of magnitude of investment tabulated in table 2.

Table 2. Level of energy efficiency measures

Level of Measures	Energy Efficiency Measures	Savings %	Payback Period Years
Low Investment Measures	EEM-05: VFD Control on SCHWP	0.28	0.7
	EEM-07: VFD on CT Fans	0.10	2.0
	EEM-09: CHWST Reset Control	0.08	1.1
Medium Investment Measures	EEM-03: Efficient Glazing System	4.11	0.9
	EEM-06: AHU Fan VFD Control	13.81	0.2
	EEM-08: SAT Reset	0.23	4.3
	EEM-10: Car Parking Lower LPD	1.31	1.2
Major Investment Measures	EEM-01: Insulated Walls	0.45	9.6
	EEM-02: Insulated Roofs	1.07	2.1
	EEM-04: Energy Efficient Chillers	3.47	2.9
Cumulative Savings & Payback Period of EEMs =		24.91	1.0

9. Conclusion

The impacts of building envelop parameters, HVAC systems design, selection and operation and lighting system design on energy consumption in the commercial building from warm and humid climate zone has been studied. The Building was modeled and simulated by using eQUEST-3.63b to investigate the building energy performance and explore potential energy savings with implementation of EEMs. The energy modeling and simulation results have shown that EEM-06 (AHUs fan VFD control) has given maximum savings of 13.81%. The results also shown minimum savings of 0.08% achieved by EEM-09 among all ten EEMs. The EEM-01 has achieved only 0.45% savings therefore resulted highest payback period of 9.6 years whereas the combined payback period was low as 1 year because of good energy saving potential in other EEMs. Hence this good payback period of 1 year make all the proposed EEMs feasible and acceptable for the proposed facility.

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10. References

[1] ASHRAE Handbook. (2001). *Fundamentals*. Atlanta, Georgia: American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc.

[2] Bae, C., & Chun, C. (2009). Research on Seasonal Indoor Thermal Environment and Residents' Control Behavior of Cooling and Heating Systems in Korea. *Elsevier Ltd., Building and Environment, 44*, 2300–2307.

[3] Batista, N. N., & Rovere, E. L. (2009). Energy Building Performance and Energy Efficency Level Evaluation. *RIO 9 - World Climate & Energy Event* (pp. 17-19). Brazil: Rio de Janeiro.

[4] Bertagnolio, S., Masy, G., et al. (2008). Building and HVAC System Simulation with the Help of an Engineering Equation Solver. *Third National Conference of IBPSA-USA* (pp. 53-60). Berkeley, California: SimBuild 2008.

[5] Dimoudi, A., & Kostarela, P. (2009). Energy Monitoring and Conservation Potential in School Buildings in the C' Climatic Zone of Greece. *Elsevier Ltd., Renewable Energy, 34* , 289–296.

[6] Erhorn, H., Mroz, T., et al. (2008). The Energy Concept Adviser - A Tool to Improve Energy Efficiency in Educational Buildings. *Elsevier B.V., Energy and Buildings, 40*, 419-428.

[7] Franken, J. (2008). *Green Building at Duke University: Potential Energy Savings and GHG Benefits Achieved by Renovating Existing Residence Halls.* Nicholas School of the Environment and Earth Sciences of Duke University.

[8] Holmes, M. J., & Hacker, J. N. (2007). Climate Change, Thermal Comfort and Energy: Meeting the Design Challenges of the 21st Century. *Elsevier B.V., Energy and Buildings, 39*, 802–814.

[9] Majali, V., Prasad, B., et al. (2005). Computer Aided Building Energy Simulation. *IE(I) Journal-AR, 86*, 28-31.

[10] Mwasha, A., Williams, R. G., et al. (2011). Modeling the Performance of Residential Building Envelope: The Role of Sustainable Energy Performance Indicators. *Elsevier B.V., Energy and Buildings , 43*, 2108–2117.

[11] Poel, B., Cruchten, G. V., et al. (2007). Energy Performance Assessment of Existing Dwellings. *Elsevier B.V., Energy and Buildings, 39*, 393–403.