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ENERGY EFFICIENCY LEVEL EVALUATION OF A COMMERCIAL FACILITY SITUATED IN HOT ANDDRY CLIMATE ZONE OF INDIA

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ABSTRACT

The researcher has thrown light on energy conservation techniques through this paper. To accomplish the study objectives multi-storey commercial building under design phase situated in Ahmadabad having hot and dry climatic conditions has been selected. A systematic assessment of HVAC system operational techniques has been focused during the study for building energy performance improvement with the help of energy simulation using eQUEST-3.63b. Building envelope and lighting system related energy efficiency measures have been investigated to improve the energy efficiency of the proposed commercial building. The study also shows the cost benefits of proposed energy efficiency measures for this building.

Key words: *commercial building, energy efficiency measures, building energy performance, energy conservation, energy simulation.*

INTRODUCTION

Thesubject building is upcoming commercial facility in Ahmadabad. To evaluate the energy efficiency level of this facility data regarding building envelope parameters such as glass, wall, roof, building HVAC system and lighting design parameters, building operating schedule etc has been studied for the proposed commercial facility. Researcher has exhibited energy efficiency measures (EEMs) which have proven to be extremely effective in selecting the prime candidates for an energy efficiency improvement effort. To reduce the operating costs energy conservation and energy efficiency offer attractive solutions. Moreover, energy efficiency can avoid the need to build new power plants - that use conventional energy sources - at little cost and with no adverse environmental impact. In addition, energy efficiency and energy conservation have other beneficialimpacts.

BUILDING GENERAL INFORMATION

This multi-storey building was an office building, which was a thirteen storey commercial building located in Ahmadabad at 23° 03' towards North and 72° 40' towards East. Gross floor area and conditioned area of the building were 329898 ft^2 and 317181 ft^2respectively. The designed maximum occupancy of the facility was 1000.

MODELING AND SIMULATION

Building energy modeling is extremely valuable for identifying energy efficiency opportunities and can go a long way towards a greener building and a greener future. Researcher has used whole building energy modeling and analysis tool eQUEST-3.63b which is a graphical user interface. It consists of a building creation wizard, an EEM wizard, and a graphical reporting feature with a simulation engine derived from DOE-2.2. It allows a graphical display of all the 3D geometry entered in the application to describe the building. As per the views shown in *figure 1* and *figure 2*, the building was beingmodeled.

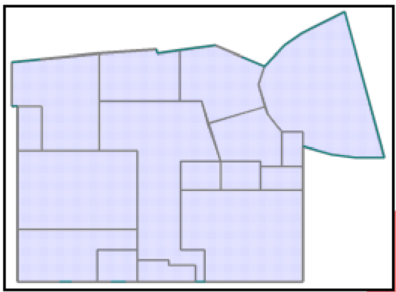

Figure 1: 2D View ofthe model

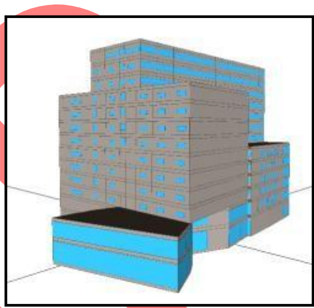

Figure 2: 3D View of themodel

Base Case Formulation

One base model of the facility with required parameters has been constructed in eQUEST-3.63b that would represent similar energy consumption pattern as well as magnitude. Input parameters influencing building energy performance has been changed within justified ranges through the comparison process to achieve good match between the simulated and designed values. The properties of materials and constructions designed for the facility has been taken as existing data sets for base case. The base model has been developed by the data accumulated through detailed survey and data provided by facility design teams**.**

Building Systems and Internal Load

The exterior walls of the building were designed as 230 mm normal brick wall with 19 mm plaster on each side. The roof was configured 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)as0.968,shadingcoefficient(SC)as0.59andsolarheatgaincoefficient(SGHC)as 0.51. The overall window to wall ratio (WWR) was 21%. The building's HVAC water side system was designed with 2 water cooled electric open centrifugal chillers. Each chiller was having equipment capacity of 550 TR. The air side system was designed 53 constant air volume (CAV) air handling units (AHU) serving the different zones of the building. The primary and secondary chilled water pumps as well as condenser water pumps were constant speed pumps. Each zone had separate thermostat control fir each AHU. The space temperature set points was designed to vary from 22°C to 28°C for summer and 20°C to24°C for winter under all conditioned zones. Fluorescent lamps and T5 lights were designed for interior as well as exterior illumination. The elevator load in the facility was 70 kW.

Thermal Zoning

The building was divided into number of thermal zones. It was essential to analyze HVAC system loads and their operational profiles. A zoning plan was developed for each floor and entered into the simulation model. Each zone was assigned various properties including lighting power density, equipment power density, occupancy rate, etc. A set of ten EEMs were added to the base case design to optimize the performance of the base case design. In order to reduce the complexity of the case study modeling for energy simulation and the thermal zones have been modified.

ENERGY EFFICIENCY MEASURES

The researcher has implemented energy efficiency measures which has lead to conservation of energy and energy saving. The following ten EEMs have been analyzed for systematic evaluation of the building energy performance:

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

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

EEM-03: The glazing has been replaced form single glazed unit to double glazed unit having U-value = 0.56 Btu/hr ft^2 °F, SF/ SHGC = 0.25 and SC = 0.29.

EEM-04: The chillers of COP 5.4 have been replaced with energy efficient chillers having COP 6.1.

EEM-05: Secondary chilled water pumps have been made equipped with variable frequency drive (VFD) control.

EEM-06: The constant speed AHU fan motor has been made equipped and controlled by variable frequencydrive.

EEM-07: The Cooling Tower (CT) fan motor has been made equipped and controlled by variable frequencydrive.

EEM-08: Supply air temperature (SAT) reset technique was employed to reset the supply temperature upward on a reduction in SAT load i.e. lower ambient temperature.

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

EEM-09: Chilled water supply temperature (CHWST) reset technique has been employed to reset the CHWST upward on a reduction in chilled water load i.e. lower ambient temperature.

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

EEM-10: The car parking lower lighting power density (LPD) has been reduced from 0.5 W/ft^2 to 0.15 W/ft^2 having lux between 100 to 150.

ENERGY USE SUMMARY

Energy end use summary shows the building energy efficiency level to evaluate the relative consumption by EEMs. The energy modeling and simulation results of the baseline building have provided comprehensive records of energy consumption breakdown of the facility. And the results for this have been shown in *figure 3*. The energy simulation results of the building has represented that the energy use in space cooling was 27%, ventilation fan 22%, area light 26% and pumps 11%. This constitutes around 86% of the building's total energy consumption. Hence, the study was focused on these areas to reduce the energy consumption. Apart from this the second major energy consumption was in area lighting accounting 26%. As shown in *figure 3* remaining 13% energy has been consumed by the miscellaneous equipments. The energy use breakdown of the building after implementing EEMs has shown in *figure 4* which reveal that the energy consumption has been reduced significantly after implementing the EEMs. Space cooling and ventilation fan energy consumption has been reduce after improving the building's envelop parameters, use of energy efficient 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 area.

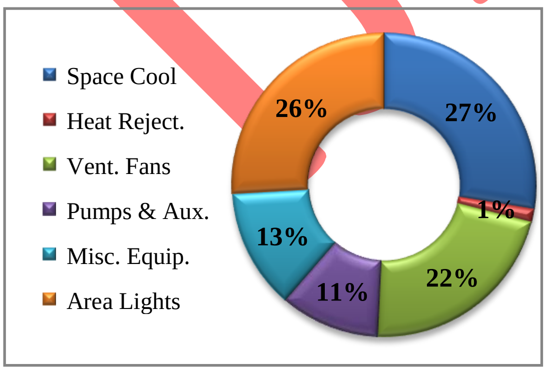

Figure 3: Base case energy consumption

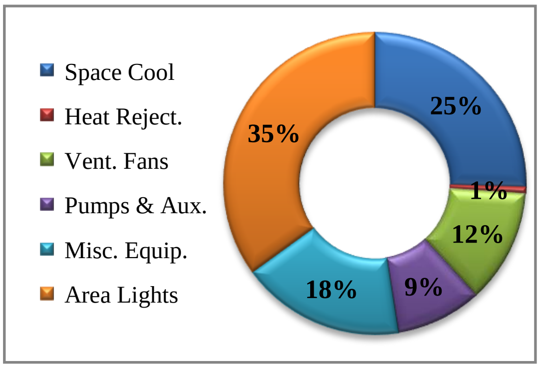

Figure 4: EEMs energy consumption

ENERGY SIMULATION RESULTS

The results of energy simulation have been shown in *table 1*. The overall savings of energy consumption 1782020 kWh, which was 27.25% over the base case has been attained by combined effect of energy efficiency measures.

Table 1: Energy simulation results

S. No.	Base Case / EEMs	Energy Consumption (kWh)	Energy Consumption (kWh/ft^{2}year)	Energy Savings (kWh)	Energy Savings (kWh/ft^{2}year)	Percentage Savings over Base Case
1	Base Case	6539112	19.820	NA	NA	NA
2	EEM-01	6487533	19.660	51579	0.160	0.79
3	EEM-02	6356736	19.270	182376	0.550	2.79
4	EEM-03	6390323	19.370	148789	0.450	2.28
5	EEM-04	6364060	19.290	175052	0.530	2.68
6	EEM-05	6293588	19.070	245524	0.750	3.75
7	EEM-06	5668298	17.187	870814	2.633	13.32
8	EEM-07	6499623	19.693	39489	0.127	0.60
9	EEM-08	6511467	19.740	27645	0.080	0.42
10	EEM-09	6534573	19.810	4539	0.010	0.07
11	EEM-10	6502899	19.710	36213	0.110	0.55
			Total =	1782020	5.400	27.25

EVALUATION OF EEMS

The savings in annual energy consumption by proposed EEMs over the base case for the building has been shown in *figure 5*. The graph shows that savings has been varying in the building because of diversity EEMscharacteristics.

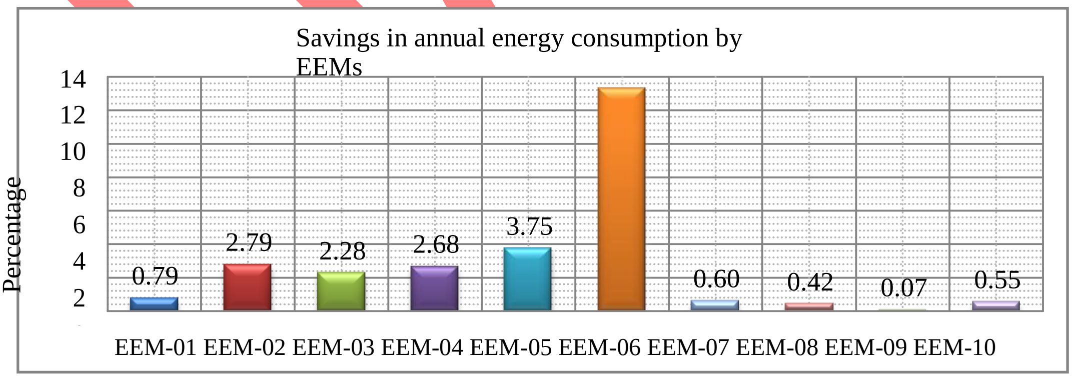

Figure 5: Savings in annual energy consumption by EEMs

The *figure 5* revealed that the maximum savings has been achieved through VFD control on AHUs 13.32% and by VFD control on secondary chilled water pump 3.75% outof total savings obtained in this facility of 27.25%. It has been also noticed that least savings of 0.07% has been found by applying reset control on chilled water supply temperature. The overall savings of 27.25% is good results by combined performance of all EEMs together.

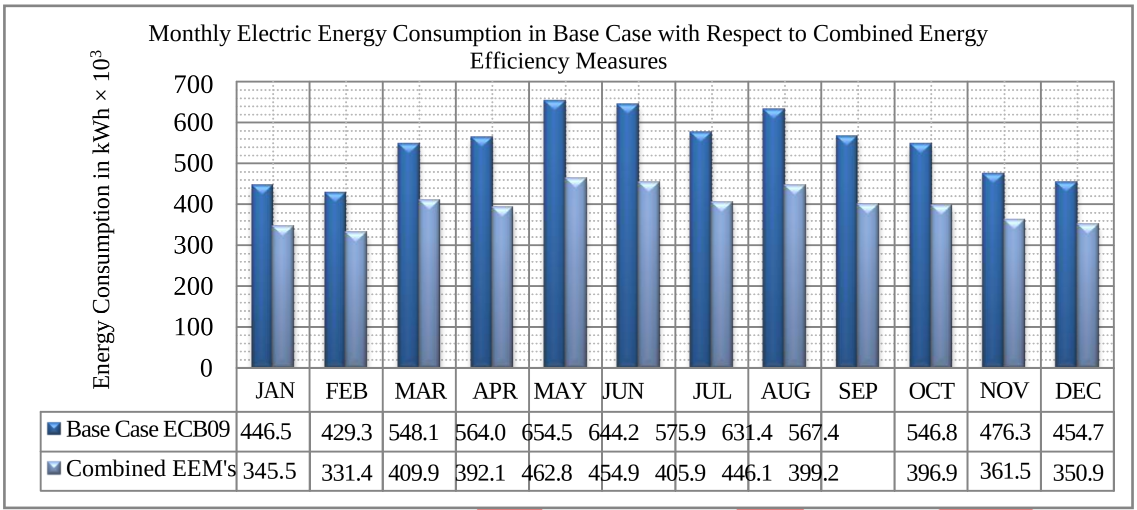

Figure 6: Effect on monthly energy consumption by combined EEMs

The *figure 6* gives insight of effect on monthly energy consumption by combined effect of EEMs in comparison to the base case energy consumption. The chart has shown consistent savings by combined effect throughout the year. The evaluation of proposed EEMs for annual energy consumption pattern of the facility also reveals that these EEMs can be categorized on the basis of magnitude of investment as tabulated in *table 2*.

(a) **Low Investment Measures**: As the name self indicates these measures are those which can be implemented through operational means without the need for significant alteration in system. And need not require significant cost for theirimplementation.

(b) **Medium Investment Measures:** These measures can be implemented through building design alterations. Thus reasonable extra cost is required for theirimplementation.

(c) **Major Investment Measures:** These kinds of measures require major investment in terms of cost for their implementation. They require system design renewal or retrofitting in proposeddesign.

Table 2: Level of energy efficiency measures

Level	Energy Efficiency Measures	Percentage Savings	Payback Period (Years)
Low Investment Measures	EEM-05: VFD Control on SCHWP	3.75	0.1
	EEM-07: VFD on CT Fans	0.60	0.4
	EEM-09: CHWST Reset Control	0.07	1.7
Medium Investment	EEM-03: Efficient Glazing System	2.28	1.1
	EEM-06: AHU Fan VFD Control	13.32	0.3

Measures	EEM-08: SAT Reset	0.42	3.8
	EEM-10: Parking & Basement Lower LPD	0.55	3.6
Major Investment Measures	EEM-01; Insulated Walls	0.79	15.1
	EEM-02: Insulated Roofs	2.79	1.2
	EEM-04: Energy Efficient Chillers	2.68	5.2
Cumulative Savings and Payback Period =		27.25	1.4

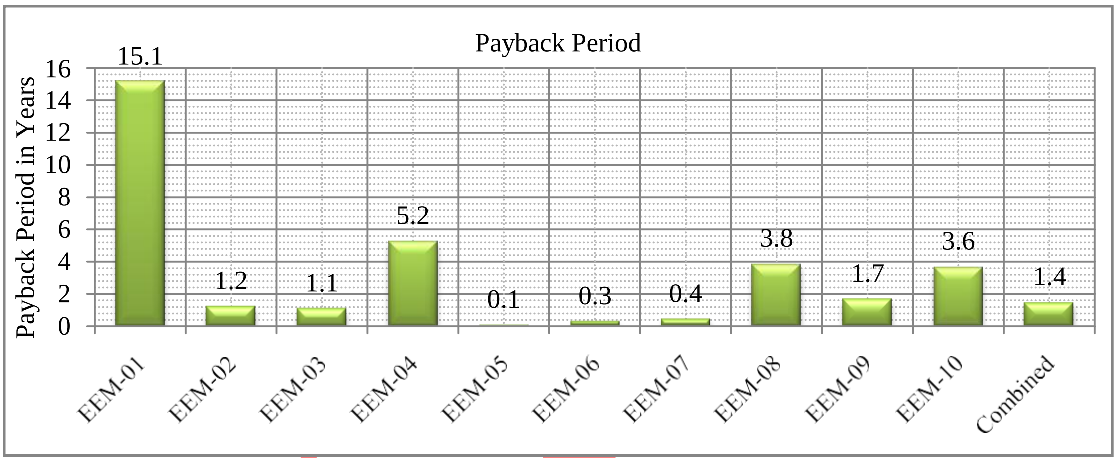

Figure 7: Effect on payback period by different EEMs

The *figure 7* has shown that the payback period for the EEMs was in the range from 0.1 to 15.1 years. While the combined payback period of all the EEMs for this commercial facility was found 1.4 years. There were five EEMs, for which the payback period was higher than the combined payback period. Out of these five EEM, the EEM-01 for XPS insulation in walls has shown extreme result. The cause of such result would be the low savings and high capital cost of investment for implementation. This has been verified by the energy simulation results. The energy savings percent because of this EEM was 0.79%only.

CONCLUSION

The energy efficiency level of the commercial facility has achieved savings in annual energy consumption by 27.25% over its base case. The evaluation of building energy system such as envelop, HVAC and lighting system for energy savings and the effect of EEMs has shown significant opportunity for energy saving in commercial facilities situated in hot and dry climate zone of India. The selected facility was modeled and simulated using eQUEST-3.63b to evaluate the building energy efficiency level and to investigate potential of energy savings by implementing EEMs. The energy modeling and simulation results have shown that EEM-01 for XPS insulation in walls has shown extreme payback period due to high capital cost of investment while EEM-06 for VFD control on AHUs has given maximum savings in annual energy consumption accounting 13.32%. The results have shown minimum savingsof0.07%hasbeenachievedbyEEM-09amongtenEEMs.Thecombinedpayback period was 1.4 years due to good energy saving potential in other EEMs. Hence this good payback period make the instigated EEM feasible and acceptable for the proposed as well as similar kind of facilities.

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