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Energy Efficient Strategies Comparison: A Corporate Building Case Study

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***Abstract**:*

The Building sector in India is the second largest consumer of energy, about 30% of total energy consumption. This percentage is likely to increase in coming years with the increase in population and improvement in living standard of people. HVAC system in modern buildings is responsible for high electricity consumption, around 60% electrical load of building. In the present work, cooling load have been calculated for a corporate building. Energy efficiency strategies like building envelope, thermal energy storage system, radiant cooling and various other strategies like efficient chiller selection, variable frequency drive for pumps and fan of HVAC system have been incorporated. Comparative study of different energy efficiency strategies have been carried out with respect to cooling load and power consumption. Heat load calculation is done zone wise as per activities done in different rooms of a corporate building. It is found that using building envelope as per ECBC (Energy Conservation Building Codes), HVAC load can be reduce around 21.5% and with using EEM (Energy Efficient Measures), to around 31.4% compared to conventional building. According to present analysis electricity consumption cost of building under case study can be reduce by about 20% and 55% respectively using ECBC and EEM compare to conventional HVAC system and their payback period are 4.5 and 4.0 years respectively.

Keywords

Green Building, ECBC, EEM, HVAC System

1. Introduction

Buildings account for a large share of the energy consumed nationally and produce 36% of the EU's CO_2 emissions [1]. Green Building (also known as green construction or sustainable building) refers to both a structure and the using of processes that which are taking care of environment and resource it should be efficient throughout a building's life-cycle: From siting to design, construction, operation, maintenance, renovation, and demolition. In other words, green building design involves autonomy between home building and the sustainable climate. This needs close cooperation of the design team, the architects, the engineers, and the client at all project stages. In creating greener structure new technology is constantly being developed, the main objective is, green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment by:

- Efficient utilization of energy, water, and other resources.
- Protecting occupant health and improving employee productivity.
- Reducing waste, pollution and environmental degradation.

Energy is the first resource to be targeted because it is highly managed, expected to continually become more efficient, and the ability to distribute and allocate it will improve disaster resiliency. ECBC is document that specifies the energy performance requirements for all commercial buildings that are to be constructed in India. It provided norms for lighting system, HVAC system, Building envelope etc. ECBC code is applicable to buildings that have connected load of 500 kW or greater. Building having conditioned area more than 1000 sq. m fall under this category [2]. Buildings impact our environment significantly. Studies show that commercial buildings are responsible for greenhouse gas emissions of about 200 tons/sq. m of floor space. Now a days modern building are being constructed in India, in which high energy consumption is taking place due to lack of well-engineered and properly designed systems. It is necessary to select efficient strategies for buildings in such a way that it will be helpful to reduce energy consumption and also it would be economical. Many tall buildings are also being constructed so, advance technologies which are energy efficient needs to be implemented to reduce the impact of the buildings on the environment. One of the way of reducing energy consumption in a Building is to apply energy efficient strategies like selection of proper building envelope and efficient HVAC system as per the requirement of Building. Accordingly in present

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paper energy saving by ECBC and EEM have been calculated for a commercial building and it have been compared with conventional system.

2. Building Envelope

Energy efficient buildings are made effectively with using proper building envelope. While the envelope does not directly use energy, its design strongly affects heating and cooling loads (HVAC energy). For example, the temperature of inside surfaces is being affected by using insulation, which can have a significant effect on comfort. Also, glazing can introduce day lighting into the space, reducing the need for electric lighting. The envelope design must take into consideration both external loads and internal loads, as well as day lighting benefits. External loads include solar gains, conduction losses across envelope surfaces, and infiltration, while internal loads include heat gain from lights, equipment, and people [3].

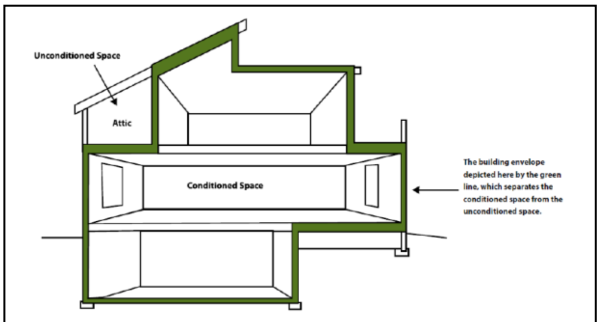

Figure 1. Building Envelope. [2]

3. HVAC System

Heating Ventilation and Air Condition (HVAC) Systems provide you desired room condition with different outside climate conditions. Mainly air cooling done by VCR systems for building services purposes. HVAC systems provide conditioned air (cooling, ventilation, thermal comfort and humidity control) to the people and locations in the hospitals, airports, industrial districts and large space buildings. HVAC systems control temperature, humidity and air quality inside the building.

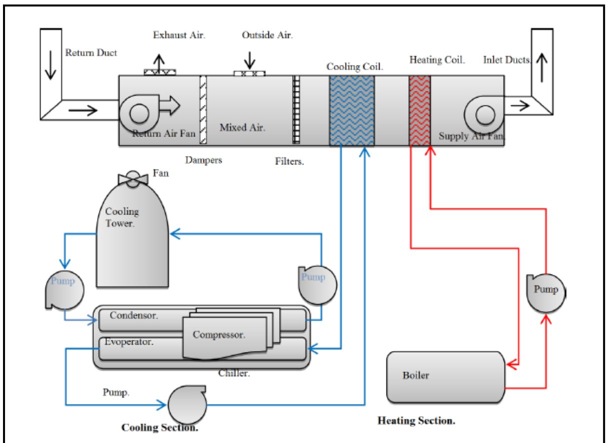

Figure 2. HVAC System.

4. HVAC Load Calculation

HVAC load have been calculated from outside design and inside design condition for a building under consideration. Also various other factors like solar heat gain, heat gain from occupancy, infiltration etc., have been calculated from equations and data given in ASHRAE and ISHRAE Handbook [4.5]:

4.1. Outside and Inside Design Conditions

Heat load is calculated with considering outdoor condition is as below,

Table 1. Outdoor Condition

	DB(^0F)	WB(^0F)	RH(%)	RH (GR/Lbh)	ENTHALPHY
Summer	111.10	73	15.36	61.11	36.36
Monsoon	100.80	90	38.71	115.12	42.38

Indoor Design Conditions considered for load calculations are as follows,

Table 2. Indoor Condition

	DB(^0F)	WB(^0F)	RH(%)	RH (GR/Lbh)	ENTHALPHY
ROOM	74.00	63.10	55.0	69.13	28.56

4.2. External Loads and Internal Loads

External and Internal load considered are as following:

External: From Walls, roofs, Windows, Partitions, Ceilings and floor.

Internal: From Lights, occupancy, appliances, and equipment, Infiltration: Air leakage and moisture migration.

5. Results of load calculations

HVAC load have been calculated for conventional building material, ECBC compliance building and EEM compliance building. Also selection of chiller made according to demand.

5.1. Conventional Building

As in this heading, conventional building material have been considered for calculation of HVAC load in this case.

Peak hourly HVAC load of a Building for conventional case is 800 TR, accordingly two water cooled chiller with 400 TR capacity have been selected for the same.

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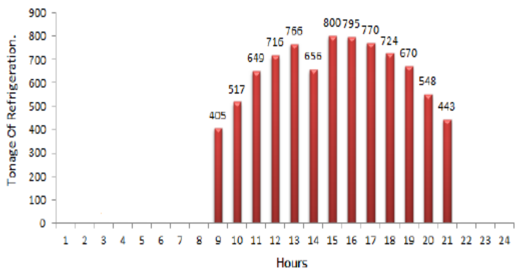

Figure 3. Hourly load for conventional.

5.2. ECBC Compliance Building

Peak hourly HVAC load of a Building for ECBC case is 628 TR, accordingly two water cooled screw chillers with 315 TR capacity have been selected to cater the demand.

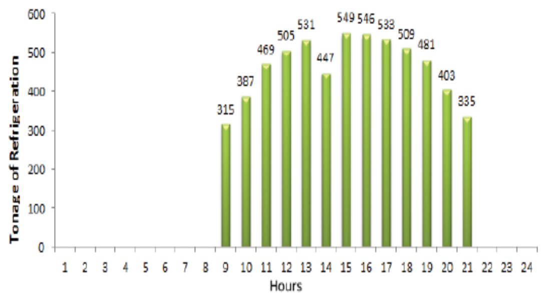

Figure 4. Hourly load for EEM.

5.3. EEMs Compliance Building

Peak hourly HVAC of a Building for EEM case is 549 TR. Here to reduce operating cost static Thermal Energy Storage (TES) along with two magnetic levitation chiller of 220 TR is selected to fulfil the demand of HVAC load.

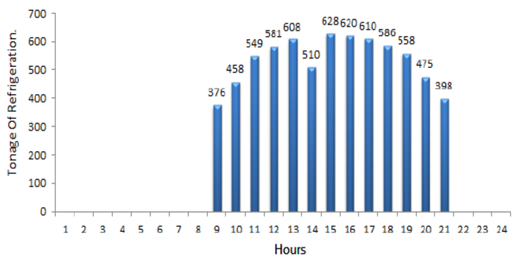

Figure 5. Hourly load for ECBC.

5.4. Comparative Yearly Energy Consumption

Month wise energy consumption of building (in kWh), for conventional, ECBC and EEMs case have been calculated and compared.

Table 3. Energy Consumption Comparision

Month	KWh (Units)		
	Conventional	ECBC	EEMs
January	108475	96858	54157
February	121250	109865	58425
March	158825	132290	70915
April	193550	143771	82412
May	211475	149576	88366
June	195825	149619	83168
July	160775	133257	71560
August	149900	123410	67954
September	159325	130032	71072
October	163900	126463	72600
November	136725	110295	63528
December	114925	97675	56314
	1874950	1503108	840469
		371842	1034481
	Savings in Energy consumption	20%	55%

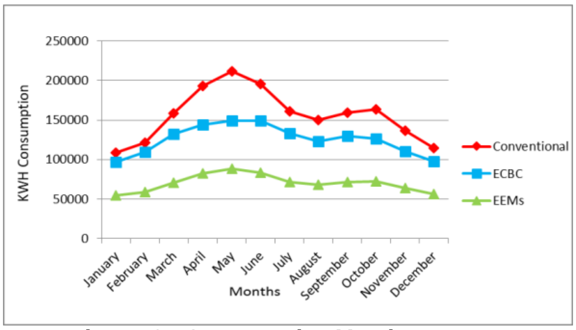

Figure 6. Comparative Yearly Energy Consumption.

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6. Payback period calculation

	CONVENTIONAL AIR-CONDITIONING SYSTEM (With out VFD)		
	INSTALLED CHILLER CAPACITY	800 TR	
	WATER COOLED SCREW CHILLER CAPACITY (2 +1 Stand by)	400 TR	
	DESCRIPTION	RATE	TOTAL COST IN RS
1	COST OF CHILLERS	15000	12000000
	COST OF STAND BY CHILLER	15000	6000000
	COST OF PUMPS AND COOLING TOWERS	10000	8000000
	COST OF LOW SIDE	30000	28590000
	COST OF AHU (RATE/CFM)	30	15202140
2	BMS COST @ 15% OF CHW SYSTEM	15%	10468821
3	TOTAL COST FOR ELECTRICAL INSTALLATION-968 KVA (UNIT RS/KVA)	7,000	6773954
4	SECURITY DEPOSIT TO ELECTRICITY BOARD (UNIT RS/KVA)	3,000	2032186
5			
6			
7			
	TOTAL CAPITAL COST FOR HVAC SYSTEM- CONVENTIONAL		89067101
	COST FOR BUILDING CONSTRUCTION (@ 1000 INR/sq ft)		

	SAVINGS IN ANNUAL OPERATING COST		
S.NO	DESCRIPTION		TOTAL COST IN RS
1	ANNUAL DEMAND CHARGES RATE/KVA/MONTH	125	1451562
2	ANNUAL POWER CHARGES @ Rs 8.5/Unit (300 wkg Days)		15937075
3	MAKE UP WATER COST (1 LAKH LTR/DAY)		1523733
4	MAITENANCE COST FOR SYSTEM PER TR	1200	960000
	TOTAL OPERATING CHARGES FOR CONVENTIONAL SYSTEM		19872370

	ECBC AIR-CONDITIONING SYSTEM (With VFD)		
	INSTALLED CHILLER CAPACITY	628 TR	
	WATER COOLED SCREW CHILLER CAPACITY (2 +1 Stand by)	315 TR	
	DESCRIPTION	RATE	TOTAL COST IN RS
	COST OF CHILLERS SCREW CHILLER WITH VFD	25000	15700000
	COST OF STAND BY CHILLER	25000	7875000
	COST OF PUMPS AND COOLING TOWERS (WITH VFD)	13000	8164000
	COST OF LOW SIDE	30000	22440000
	COST OF AHU (RATE/CFM)	35	12858860
	BMS COST @ 15% OF CHW SYSTEM	15%	10055679
	TOTAL COST FOR ELECTRICAL INSTALLATION-741KVA(UNIT RS/KVA)	7,000	5184692
	SECURITY DEPOSIT TO ELECTRICITY BOARD (UNIT RS/KVA)	3,000	1555408
	TOTAL CAPITAL COST FOR HVAC SYSTEM- ECBC		83833639
	ADDITIONAL COST FOR GREEN BUILDING PARAMETERS (@ 1150 INR/sq ft)		22839750
	TOTAL CAPITAL COST FOR ECBC SYSTEM		106673389
	ADDITIONAL INITIAL COST IN RS		17606288

S.NO	DESCRIPTION		TOTAL COST IN RS
1	ANNUAL DEMAND CHARGES RATE/KVA/MONTH	125	1111005
2	ANNUAL POWER CHARGES @ Rs 8.5/Unit (300 wkg Days)		12924981
3	MAKE UP WATER COST(78000 LTR/DAY)		1199940
4	MAITENANCE COST FOR SYSTEM PER TR	1200	753600
	TOTAL OPERATING CHARGES FOR CONVENTIONAL SYSTEM		15989526
	SAVINGS IN OPERATING COST IN RS		3882843
	SAVINGS IN OPERATING COST IN RS (15 Years)		58242651
	ACTUAL SAVINGS IN OPERATING COST IN RS (15 Years)		40636363
	Pay Back Period (Years)		4.5

HYBRID AIR-CONDITIONING SYSTEM		
INSTALLED CHILLER CAPACITY	555 TR	
WATER COOLED SCREW CHILLER CAPACITY (2 +1 Stand by)	220 TR	
THERMAL ENERGY STORAGE	1232 TRH	
FRESH AIR LOAD ON DOAS (CONSIDERING 30% HEAT RECOVERY)	113 TR	
SLAB COOLING LOAD	220 TR	
PHE CAPACITY FOR RADIANT COOLING	220 TR	
DESRIPTION	RATE	TOTAL COST IN RS
COST OF BASE (MAGNETIC LEVITATION) CHILLERS	32000	14080000
COST OF STANDBY CHILLER (VFD SCREW)	25000	5500000
COST OF PUMPS AND COOLING TOWERS (WITH VFD)	13000	7137000
COST OF LOW SIDE	30000	14190000
COST OF AHU (RATE/CFM)	35	5590480
COST OF DOAS (RATE/CFM)	130	4700800
RADIANT COOLING SYSTEM (SLAB COOLING)	200	24528400
BMS COST @ 15% OF CHW SYSTEM	15%	11359002
TOTAL COST FOR ELECTRICAL INSTALLATION-499 KVA (UNIT RS/KVA)	7000	3490483
SECURITY DEPOSIT TO ELECTRICITY BOARD (UNIT RS/KVA)	3000	1047145
COST OF THERMAL STORAGE SYSTEM (CHILLED WATER)	2400	2956800
COST OF TANK FOR TES (WITH INSULATION)	14000	9800000
TOTAL CAPITAL COST FOR HYBRID HAVC SYSTEM		104380110
ADDITIONAL COST FOR EEM PARAMETERS (@ 1175 INR/sq ft)		26646375
TOTAL CAPITAL COST FOR EEM SYSTEM		131026485
ADDITIONAL INITIAL COST IN RS		41959384

DESCRIPTION		TOTAL COST IN RS
ANNUAL DEMAND CHARGES RATE/KVA/MONTH	125	747961
ANNUAL POWER CHARGES @ Rs 8.5/Unit (300 wkg Days)		7143984
MAKE UP WATER COST(63000 LTR/DAY)		966984
MAINTENACE COST FOR SYSTEM PER TR	1000	549000
TOTAL OPERATING COST FOR HYBRID SYSTEM		9407929
SAVINGS IN OPERATING COST IN RS		10464440
SAVINGS IN OPERATING COST IN RS (15 Year)		156966603
ACTUAL SAVINGS IN OPERATING COST IN RS (15 Year)		115007220
Pay Back Period (Years)		4.0

7. Conclusions

Following conclusions have been made from present work:

- Hybrid HVAC system or Building compliance with EEMs results in to considerable energy saving, also impact on environment is less.
- For the commercial building under consideration about 21.5 % and 31.4% saving in cooling load results compared to conventional building, using ECBC and EEMs compliance building respectively.
- Payback period have been calculated from market cost of chiller and other component and average life of system, which indicates 4.5 years for ECBC and 4 years for EEMs compliance building respectively.

8. References

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