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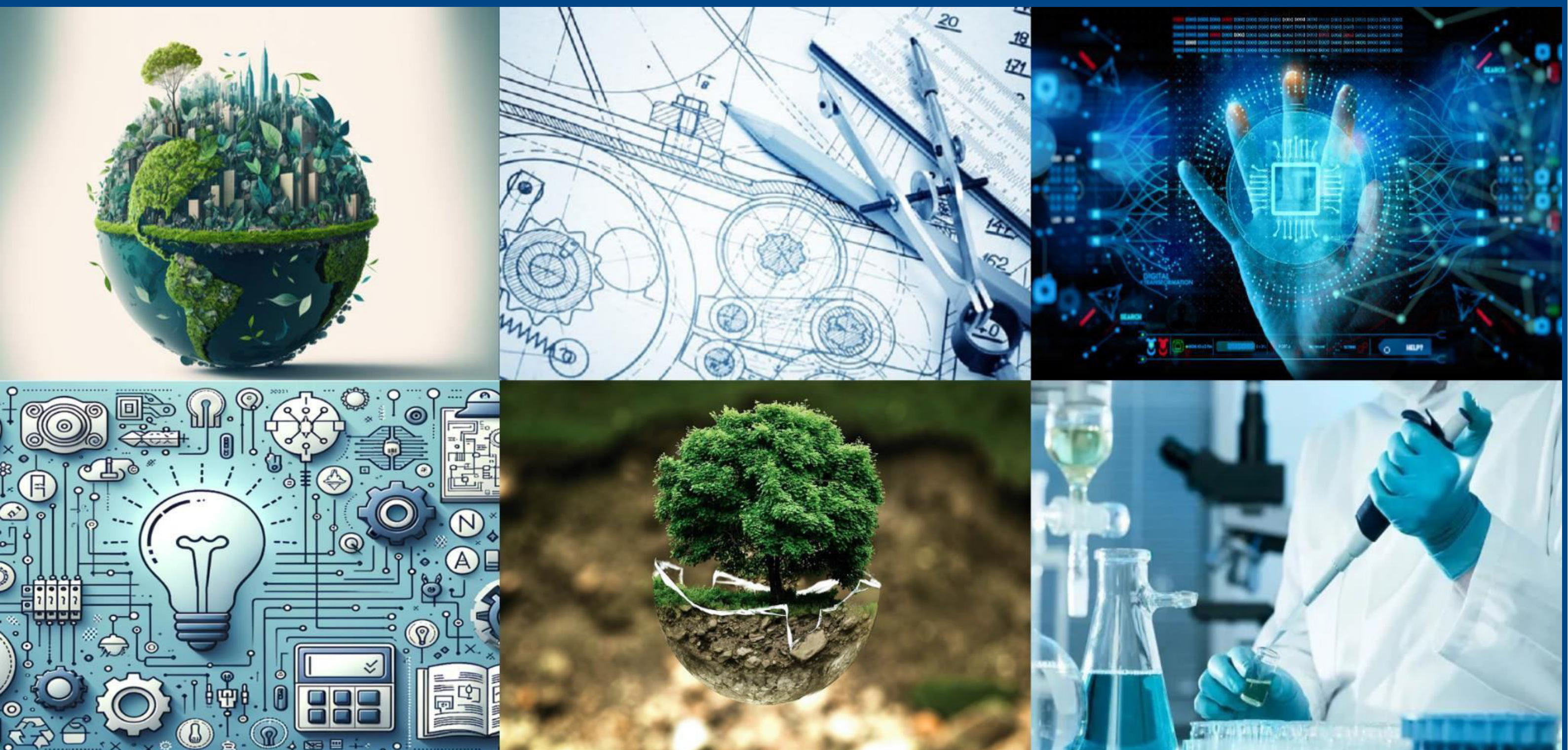

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ECBC Compliance Validating Design Concept & Energy Simulation Results in a Case Study of a Commercial Energy-Efficient Building

Chitra Dhakar, Devendra Kumar Doda

Research Scholar, Department of Electrical Engineering, Vivekananda Global University, Jaipur, Rajasthan, India

Associate Professor, Department of Electrical Engineering, Vivekananda Global University, Jaipur, Rajasthan, India

ABSTRACT: Buildings that are sustainable and energy-efficient are crucial for lowering energy usage, minimizing environmental impact, and fostering a more sustainable future. Buildings that are both environmentally responsible and economically effective can be made through implementing energy-efficient design ideas, choosing sustainable building materials, and supporting sustainable building operations and maintenance.

India has not implemented many ECBC & energy-efficient construction techniques in commercial buildings due to a number of problems. The absence of genuine real-life examples of energy-efficient buildings using data on performance is one of the contributing factors. Such case studies are required to persuade builders and building design teams about the benefits of energy-efficient structures, as well as government bodies (charged with implementing ECBC). Due to the majority of buildings without an energy information system (EIS) or having one that is malfunctioning, monitoring a building's energy performance can be difficult.

This paper provides a case study of a composite climate (Jaipur) day-use corporate office structure that is energy efficient. The paper includes information on:

a. The building's energy-saving initiatives.
b. Conclusions from the building's energy simulation during design.
c. The outcomes of examining ECBC compliance

The use of insulation in the outer walls and roof, an optimized window-to-wall ratio, effective glazing, an efficient air conditioning unit, LED lighting, and a roof-top solar PV system are all examples of energy efficiency measures (EEMs) for this structure 51.40% of total savings, according to the statistics.

I. LITERATURE SURVEY

[1]. According to the Brundtland Report, a 1987 United Nations report, sustainable development is the process of creating cities, towns, enterprises, communities, etc. that "meets the requirements of the present without compromising the ability of future generations to meet their own needs." A number of United Nations documents, notably the 2005 World Summit Outcome Document (USGBC, 2011), refer to economic development, social development, and environmental protection as the "interdependent and mutually reinforcing pillars" of sustainable development. Today, there are more sustainable buildings than ever before, and evaluating them is a common practice

[2]. (Berardi, 2012). Buildings are receiving more attention as a result of their rising energy use and greenhouse gas emissions, which in industrialized nations account for thirty per cent and forty per cent of overall consumption, accordingly. (IEA, 2010) (Chen, et al, 2012).

[3]. An additional essential component of energy generation is the use of renewable energy sources. The intermittent nature of renewable energy sources and their comparatively high maintenance costs are the main reasons why they are recognized to be less cost-effective than conventional electric energy conversion systems. But there are several benefits to using renewable energy sources, including less reliance on fossil fuels and less carbon dioxide released into the

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atmosphere (Baños, et. al, 2011).

[4]. According to a study by Al-Ashwal & Budaiwi (2011) titled "Energy savings due to daylight & artificial lighting integration in office buildings in hot climate", a suitable integration of daylight and artificial lighting can significantly reduce illumination quality and energy consumption. Their research examines how well office buildings in hot climates integrate both artificial and natural light in terms of energy performance. The effect of various window design characteristics, such as window area, height, & glazing type, on a building's energy performance was investigated using a parametric approach. The results showed that when effective day lighting with artificial lighting integration is achieved, up to a 35% decrease in lighting energy consumption and a 13% reduction in overall energy consumption can be realized. The study also demonstrates that, due to differences in solar heat transmission and exposure due to window type and orientation, the overall consumption of energy increases linearly with window area but at varying rates. At a 20% window-to-wall ratio, the heat mirror double glazed window consumed 46 kWh/m2/year less energy than the single glazed window in the east and 18 kWh/m2/year less energy in the north. The difference gets more noticeable as the window's size grows.

[5]. Joseph Eto (1988) In his work "On Using Degree-days to Account for the Effects of Weather on Annual Energy Use in Office Buildings" published in 1988, Joseph Eto assesses how well weather affects energy use. The examination simulated the use of gas and electricity in two big office block prototypes situated in five different regions across the United States. In order to pinpoint problems with implementing the techniques to office buildings, he evaluates the evolution of degree-day-based, weather-normalization techniques. He then assesses the accuracy of the strategies using simulated data. According to his analysis, the majority of methodologies worked ok for the five locations in the United States and the two office block prototypes under consideration; accuracy in estimating annual consumption is often better than 10%.

[6]. Ban-Huat NG & Akasah Zainal Abidin (2013) have determined the issues with energy-efficient architecture in Malaysia that have an impact on occupant comfort. The results of their study indicated that the majority of building occupants are dissatisfied with the thermal comfort & illumination conditions. Better Indoor Environment Quality (IEQ) performance is not a guarantee when a facility is accredited using sustainable building rating techniques.

II. INTRODUCTION

India's rapidly rising energy consumption is a problem because it has a big impact on the economics, environment, and energy security of the nation. According to the data given, India's total installed capacity for electricity generation has grown at a CAGR of 8.52% over the past ten years, and under the "Determined Effort Scenario," it is predicted to reach 1145 GW by 2047. Numerous reasons, including population expansion, urbanization, industrialization, and economic expansion, are responsible for this rise in energy demand. Adopting sustainable and effective energy policies and practices is essential because as the nation expands, the need for energy is anticipated to increase even more. India has set high goals for energy efficiency and renewable sources of power in order to meet this issue. According to the National Action Plan on Climate Change (NAPCC), by 2030, renewable energy will make up 40% of the nation's energy mix, while energy efficiency will have increased by 20%. In order to encourage renewable energy, energy efficiency, and sustainable development, the government has also started a number of programs and projects. Figure 1 shows that The majority of the electricity is consumed by the industry (44%) building sector.

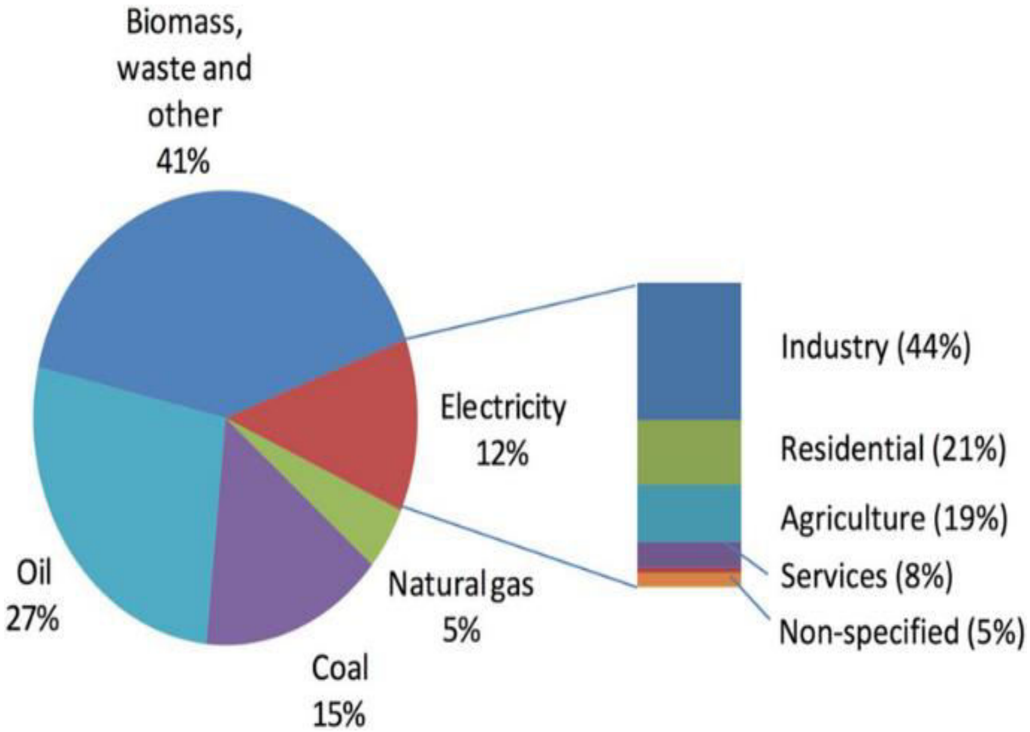

Figure 1:India's Electricity Consumption

Projections based on many circumstances, As India attempts to meet the expanding energy needs of its population while lowering its carbon footprint, the country's energy landscape is experiencing a substantial transition. While coal still makes up the majority of India's energy mix, there is a rising focus on renewable energy sources like solar and wind power.

Overall, India's energy situation is fast changing, with an increasing focus on renewable energy and energy efficiency. India is making great strides towards a more sustainable energy future, even if there are still many obstacles to overcome, such as the need to increase access to electricity in rural regions and lessen the nation's reliance on fossil fuels.

India's net energy generation for the fiscal year 2020–21 was 1,387 billion kilowatt-hours (kWh), down 2.2% from the previous year, according to the Central Energy Authority (CEA). The thermal power sources that made up 71% of the total, including coal, natural gas, and oil, were responsible for producing the majority of this electricity.

Corporate building energy efficiency has been the focus of regulatory efforts in India. The Bureau of Energy Efficiency (BEE) laid out the Energy Conservation Building Code (ECBC) in 2007 to energize energy effectiveness in as of late fabricated and sizable business and institutional designs. Be that as it may, execution of the ECBC is discretionary, and it just becomes fundamental in the state in the wake of being educated by the applicable state government. ECBC is right now expected in 22 states, despite the fact that trying the law has been testing.

ECBC and other mandatory building energy proficiency codes are believed to be urgent for mainstreaming building energy effectiveness in new development in arising economies. Furthermore, it has been seen that building energy productivity rules are more broadly acknowledged in chilly temperature districts than in warm environment parts (Liu et al. 2010). Building energy efficiency rules must be implemented successfully despite several obstacles in rising nations, which is why a multifaceted strategy is required.

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The production of first class contextual analyses of energy-proficient business structures is one of the vital parts of this multi-pronged methodology, especially for nations like India that are situated in the district of warm environments. Rather than utilizing real energy execution checking, an enormous number of contextual analyses on energy-effective ad structures which are presently open in India rely upon reenactments of building energy execution.

Accordingly, manufacturers/engineers and building fashioners need trust in the viability of ECBC, building energy proficiency plan methods, and the consequences of building energy simulations (E-QUEST 3.65 VERSION).

A case study of a commercial building is presented in this paper. The article provides information on:

a. The building's energy-saving initiatives.
b. The outcome of the building energy simulation throughout the design phase of the building using software e-Quest version 3.65.
c. The outcome of evaluating conformity with ECBC standards.

Regarding the building's design: The building (Figure 2) is the head office of a corporate building, situated in Jaipur (composite climate). And figure 3 shows the floors plans of the building which are develop in cad software.

Figure 2::Corporate Building.

These are this building's main features:

- Total Built-up area: ~110,000 m^2 (excluding basementparking and service area)
- Number of floors: Five (G+4).
- Number of users: 344
- Types of spaces: Offices, Training Rooms.

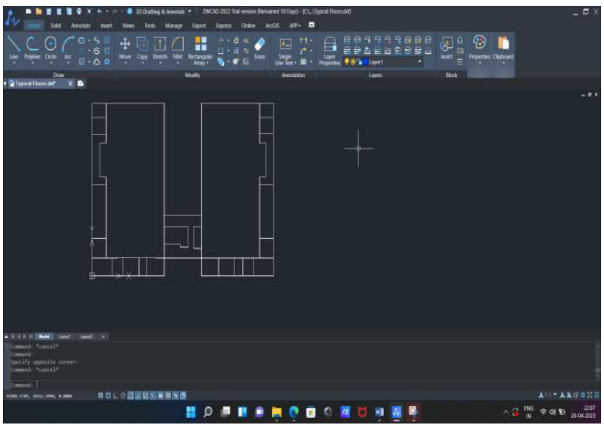

Figure 3:Ground floor plan of the building

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Implemented energy-saving measures and a renewable energy system: During the design session, minimizing heat gains was the key focus. enhancing natural light, installing energy-saving lighting and cooling equipment, and incorporating renewable energy. The following EEMs were chosen and put into practice throughout the construction phase. The EEMs consist of:

Roof Assembly (Figure 4): Proposed-Roof Construction consist in order from outer to interior materials are high SRI tiles 10mm, concrete screed 25mm, Brickbat Coba 75 mm, Cement plaster 20mm, RCC Slab 200mm, Rubber Insulation 19mm, having a U-value **of 0.190 Btu/h.ft2.degF.**

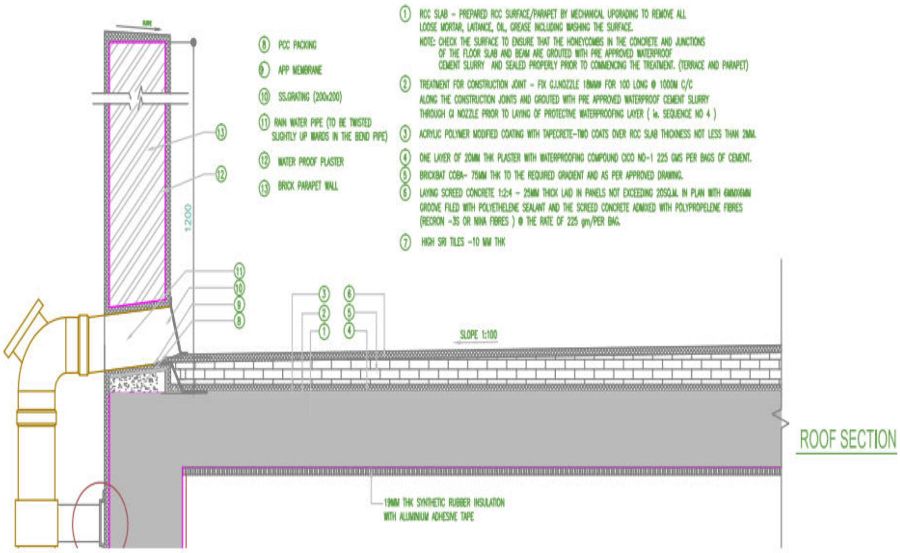

Figure 4:Roof Insulation

Wall Assembly (Figure 5): Proposed Construction wall Consist of in order from outer to interior materials are Stone Cladding 45mm, Plaster of 20mm"Air Gap, brick wall 230 mm and a plaster of 20mm having a U-value of **0.245 Btu/h.ft2.degF**

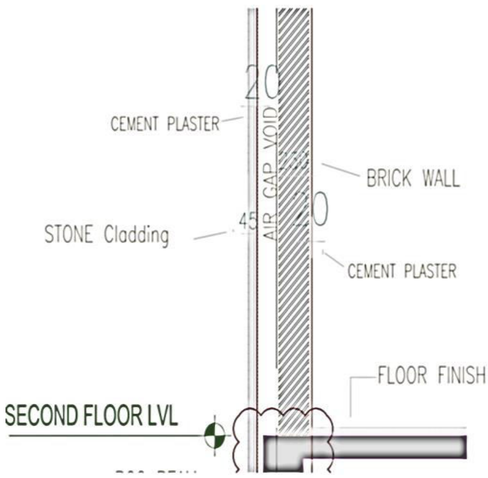

Figure 5:Wall insulation details.

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Efficient glazing (Figure 6): "Double Glazed glass with a SHGC of 0.20 and U- value 0.28 Btu/h.ft2.degF- South, East, West Glazing, Single Glazed Glass with SHGC of **0.46** & U- **factor 0.95 Btu/h.ft2**.degF- North Glazing.

Ecosense Excel – Performance Parameters

Ecosense Excel - 6 mm (Solar Control Double Low-E Glass) - 12mm (airgap) - 6 mm (Clear Glass)								
Product Name	Shade	Code	Visible Light			SF	SC	U-Value
			Transmission	Reflection				
				External	Internal			
			%	%	%	%		W/m²K
Clear Pearl	Clear	DC 41/23	41	19	13	23	0.26	1.6
BLue Pearl	Blue	DH 27/19	27	12	13	19	0.22	1.6
Green Pearl	Green	DN 34/20	34	15	13	20	0.23	1.6
Clear Sparkle	Clear	DC 46/25	46	19	17	25	0.29	1.6
Blue Sparkle	Blue	DH 31/20	31	12	18	20	0.23	1.6
Green Sparkle	Green	DN 41/22	41	17	18	22	0.25	1.6

Figure 6:Glazing details

Energy-saving lighting LPD: A 0.49 W/m2 lighting power density (LPD) was attained using LEDs.
An air-conditioning system that is energy efficient is employed throughout the building, which is centrally located.

Solar PV(Photo-Voltaic) system (Figure 7): A 100kWp grid is associated rooftop top sun powered PV photovoltaic framework with net metering is introduced to somewhat cover the structure's energy needs. It ought to be noticed that during energy recreations, the sun powered PV framework's commitment was not considered while ascertaining the EPI.

Figure 7: SPV system at the rooftop

To calculate the advantages of EEM integration, the building's energy simulation was done using e-Quest software version 3.65. The energy simulation's main outcomes were as follows:
The proposed case's HVAC systems have been modelled in accordance with the available HVAC plans.
Various VRF units are available, depending on the HVAC needs of the zone. The Baseline-System is modelled as a System per floor and complies with all the requirements of ASHRAE standards (norms) 90.1-2010 - Appendix G because the Baseline Model was created in accordance with ASHRAE design principles.

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LEED Certification: A widely used rating system that evaluates a building's environmental performance and promotes eco-friendly building techniques is called LEED (Leadership in Energy and Environmental Design). This structure is saving 38.36% of its costs. It is able to earn a LEED V4 NC EA credit of 15 points. Improve energy efficiency.

III. ENERGY MONITORING

Building energy performance was monitored to better understand the building's real energy performance and to contrast it with the estimated energy performance obtained through energy simulation. The energy monitoring method was used because the structure lacks an EIS.

Collection of Electricity Bill

A year's worth of electrical bills (from May 2015 to April 2016) were gathered. These numbers were used to compute the building's EPI on a monthly and annual basis. The billing information was also compared to information from a log-book kept by the building operating team members that recorded the number of hours the HVAC systems was used & how much electricity was consumed on a regular basis.

Calibrated Energy Simulation Model

Detailed equipment specifications and system performance measurements are based on the information gathered, and an energy simulation model is created on e-Quest software version 3.65 which is shown in Figure 8.

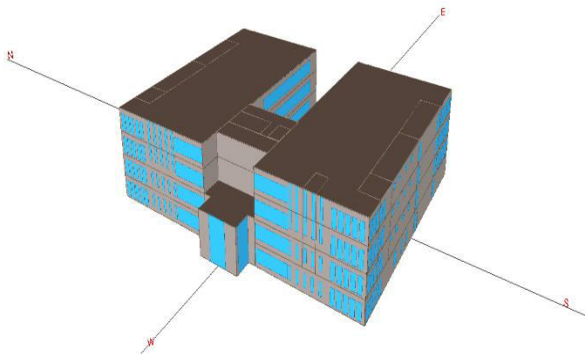

Figure 8:e-Quest Model (3-D model).

To balance the monthly energy, use with the monthly energy bills

For the thorough monitoring period, vs the energy utilization of different end-utilizes (lighting, machinery, HVAC, etc.).

This model's main goal was to: (1) compute the annual energy usage based on careful monitoring that was conducted. and (2) to estimate the energy savings from the addition of solar energy as a renewable energy source.

ECBC Compliance

The "Energy Conservation Building Code" is abbreviated as ECBC. The Bureau of Energy Efficiency (BEE), an organization in India, created this code to establish the minimal requirements for a building's energy efficiency. By outlining regulations for lighting, heating, ventilation, air conditioning, and other systems, the code strives to encourage energy efficiency in buildings. For all commercial buildings and structures with a connected load of 100 kW or more, the ECBC is required. The code's development aims to cut down on energy use in buildings, encourage the use of renewable energy sources, and lower greenhouse gas emissions.

ECBC compliance was checked using the "whole building performance method." To do this, an energy simulation model must be prepared for the two scenarios of ECBC Prescriptive and as Planned. All of the simulation inputs for the "ECBC Prescriptive" case, including external wall U-factor, rooftop U-factor, fenestration SHGC, VLT and U-factor, (LPD) lighting power thickness, air conditioning framework EER, and so on, were gathered from ECBC. All reenactment inputs were utilized as determined limit and plan determinations in the "As Planned" condition. Indoor regulator set focuses,

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plans, interior increases, inhabitant loads, and other inputs that affect how a building operates were left constant in all scenarios. Furthermore, the compliance of ECBC with all regulations was verified.

IV. RESULTS AND DISCUSSIONS

Correlation of energy execution (Simulation vs actual)

The Baseline case model strictly complies with the "Performance Rating Method" described in ASHRAE Standards 90.1-2010 Appendix G. Based on the outcomes of the energy simulation, it has been determined that the minimal energy performance calculator's average yearly electric consumption is 1489.706* 103 kWh seen in Figure 9.

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	27.6	32.4	53.4	64.2	100.4	115.5	88.0	88.3	86.4	66.6	45.6	33.6	802.0
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.7	0.1	-	-	-	-	-	-	-	-	0.0	0.4	1.2
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	9.6	11.1	17.9	19.0	24.0	24.4	19.1	20.7	20.5	19.7	15.1	11.8	212.9
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	1.4	1.3	1.4	1.3	1.4	1.3	1.4	1.4	1.3	1.4	1.3	1.4	16.3
Misc. Equip.	40.0	37.9	45.3	40.1	43.5	43.4	40.3	45.2	40.1	41.8	39.9	40.3	497.7
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	22.6	21.4	25.4	22.7	24.5	24.3	22.8	25.4	22.7	23.5	22.5	22.8	280.4
Total	102.0	104.1	143.3	147.4	193.8	209.0	171.5	181.0	171.0	153.0	124.4	110.2	1,810.6

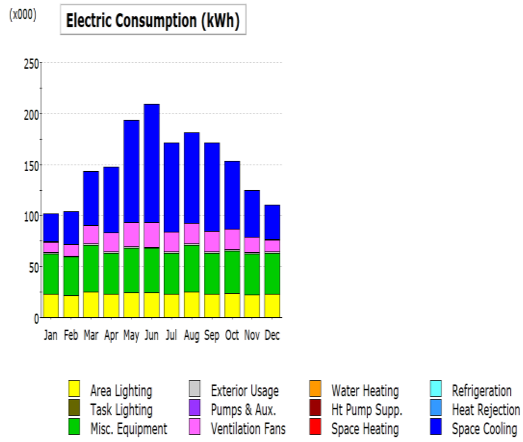

Figure 9:Baseline Simulated Results.

The Proposed model is planned in e-Quest version 3.65 with its different boundaries like Occupancy, lighting, air conditioning (HVAC). Air conditioning (HVAC) is displayed per mechanical floor plans. The complete yearly Electric Energy Utilization for the proposed case was 1075.1*100 kWh seen in Figure 10.

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	5.3	7.8	16.0	19.5	30.3	33.7	30.3	34.2	28.3	20.8	12.8	7.7	246.6
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	0.4	0.2	0.1	0.0	-	-	-	-	-	-	0.2	0.4	1.3
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	6.9	6.8	9.0	8.9	10.1	10.2	8.7	9.3	9.1	8.9	7.6	7.2	102.7
Pumps & Aux.	-	0.2	2.2	3.6	5.4	5.5	3.0	2.6	4.1	3.3	1.2	0.1	31.2
Ext. Usage	0.7	0.6	0.7	0.6	0.7	0.6	0.7	0.7	0.6	0.7	0.6	0.7	7.7
Misc. Equip.	40.0	37.9	45.3	40.1	43.5	43.4	40.3	45.2	40.1	41.8	39.9	40.3	497.7
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	12.3	11.6	13.8	12.3	13.3	13.2	12.4	13.8	12.3	12.8	12.2	12.4	152.4
Total	65.6	65.0	87.0	85.1	103.2	106.6	95.3	105.7	94.6	88.2	74.6	68.7	1,039.6

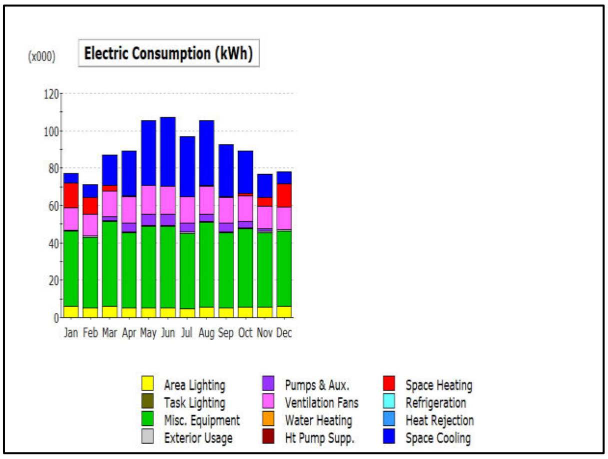

Figure 10:Proposed Simulation Results

Key reasons for these differences are:
The ISHRAE climate information record, which offers hourly information for a year with long haul estimated information, was utilized to run the recreation. The climate throughout the span of the checking time frame might stray from those measurements when contrasted with the information used in the energy reenactment. While the HVAC system was assumed to be operating during this time in the simulation, it was discovered while monitoring that the use of HVAC will less from November to Mid-March.

During the modelling process, only weekends (Saturday and Sunday) were taken to be counted as holidays; nevertheless, there were actually 20–30 extra-holidays.

The outcomes of energy monitoring were integrated to build a "calibrated with baseline simulation of energy model," that is discussed in greater detail in the following sections. These results included the real schedule for occupancy, in order lighting, equipment, as well as HVAC system performance.

ECBC Compliance Analysis Results
From the above simulation-results demonstrates that the energy consumption of the "As Proposed" case is approximately 51.40% lower than the "ECBC Prescriptive" case, demonstrating that the building complies with ECBC regulations. The "whole building efficiency method" was employed in this to determine whether or not the building's design complies with ECBC.

Table 1:Comparision Results in terms of energy savings and cost.

Case	Energy	Cost
Proposed consumption	1039580	152808
Baseline consumption	1816067	266944
Solar Capacity Installed	100 kW	
Energy Generation from Renewable Energy	156963	23072.0
Proposed consumption excluding renewables	882617	129736
Savings	51.40%	51.40%
No. of Points Achieved	**18**	

For existing structures, BEE also offers a star rating system based on a single year's worth of energy usage (EPI) data. A building receives a 5-star rating (the highest possible) for a day-use office building in a composite-climate (such as Jaipur). A 5-star rating under BEE's star rating scheme is readily achieved by the building.

V. CONCLUSION

For ECBC to be widely adopted across the nation, high-caliber case studies drawn from monitored energy performance are required. The case study in the essay focuses on a Jaipur office block and covers:

a) The building's energy-saving initiatives.
b) The outcomes for the building energy modelling performed during the design phase.
Findings from the evaluation of ECBC compliance
The use of insulation in the external walls and roof of the building, an optimized window-to-wall ratio, efficient glazing, a high efficiency HVAC equipment's, LED lighting, and a rooftop solar photovoltaic system are all examples of energy efficiency measures (EEMs). The development of a monitoring approach was necessary because the building lacks an EIS. which included (i) examination of annual monthly energy bills; and (ii) a calibrated energy simulation model.

The case study demonstrates how one can obtain a reasonable understanding of a building's energy performance. Such case studies should be many. This would encourage developers, builders, and other professionals in the building industry to include energy-saving techniques into their projects, resulting in an increase in the number of ECBC-compliant structures.

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