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Case Study: ECBC Compliance Building, Wisdom Ark School Mohali, Punjab

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Abstract: ***The primary purpose of this paper is to check the effect of the imposition of ECBC(Energy Conservation Building Code)-2017, describe and provide the likely energy consumption of the Wisdom Ark School, Mohali, Punjaband to assess the percentage savings of the proposed building over the standard building as per ECBC-2017 by Whole Building Performance method. The whole building simulation software performs hourly simulation in an approved software and derives the estimated energy consumption for a given building. The software used for the analysis of the building's energy performance is eQUEST Version 3.65. In line with the requirements outlined in ECBC, the software is a program based on the DOE-2.2 simulation engine project that has gone for ECBC compliance through whole building simulation and it has achieved 8 % energy savings compared to standard ECBC model with an EPI of 89.5 & EPI ratio of 0.92.***

Keywords: ECBC, Energy Conservation, Energy Simulation,Composit Climate

1. Introduction

The Energy Conservation Act of 2001 empowered the central government to prescribe an Energy Conservation Building Code (ECBC). ECBC was launched in May 2007 evolved by an Expert Committee, set up by Bureau of Energy Efficiency (BEE), India. ECBC, Energy Conservation Building Code is a document that specifies the energy performance requirements for all commercial buildings that are going to be constructed in India and is mandated by EC Act, 2001. Subsequently, with the amendment in Energy Conservation Act, ECBC has been updated to expand its scope, incorporate technological advancements, and respond to the changed market scenario.Accordingly, ECBC 2017 has been revised to integrate advanced technologies.

Supplementary parameters included are associatedwith renewable energy integration, ease of compliance, incorporation of passive building design strategies and, pliability for the designers. The major updates to the code arethe incorporation of incremental, voluntary energy efficiency performance levels. The specialty of ECBC 2017 is that it is the first building energy codethat is going to recognize beyond code performance. In ECBC 2017, three levels of energy performance standards have been provided. In ascending order of energy efficiency, these are three levels are- ECBC, ECBCPlus, and superb. The stagnancy to the minimum requirements specified for the ECBC level of efficiency would indicate compliance with the building code. The other two energy efficiency levels will not be mandatory for the client, the other two are voluntary. These features were incorporated so that the building industry and upcoming market can adapt to the energy efficiency standards.

Govt. of India and state governments can modify the ECBC 2017 according to the climatic conditions of the states as per the Energy Conservation Act, 2001. After the changes in code, the state government can notify in Govt. gazette for its proper enforcement by making it mandatory for the commercial buildings which have a connected load of 100 kW or maximum demand of 120 kVA. This code is mandatory for Commercial purpose buildings only, not applicable for private residential buildings.

Site Information

The project location is Wisdom Ark School is an upcoming Senior Secondary School at Village ChapparChiri, Sector - 92a, Sas Nagar. The building has Ground+3 Floors. The total built-up area of the project is around 74102 ft2/6884.30 m2. The project is now at the construction stage and the project is implementing all the measures which make the building comply with ECBC. The project is going for ECBC compliance through the Whole Building Simulation Approach. The project is using LED lights and split systems with a higher COP.

Building Name	Wisdom Ark School at Village ChapparChiri, 92a, SAS Nagar, Mohali, Punjab
Building Type	School
Location	SAS Nagar Mohali
Climatic Zone	Composite
Built-up Area, ft^2	74,102 ft^2
Conditioned Area, m^2	29,322 ft^2
ECBC compliance achieved	ECBC-2017
Energy Consumption- School (Baseline Case), kWh/year	6,72,504
Energy Consumption Proposed Case, kWh/ year	6,15,522
Energy Saving Achieved, kWh/ year	56,431
EPI (Baseline Case), kWh/m2/year	97.7
EPI (Proposed Case), kWh/m2/year	89.4
EPI Ratio	0.92

2. Whole Building Performance: Energy Modelling and Simulation

2.1 Summary

The whole building simulation software performs hourly simulation in an approved software and derives the estimated energy consumption for a given building. Energy conservation measures may be applied in addition to the mandatory requirement to achieve improved performance over the ECBC baseline. This method gives the necessary flexibility to the owner over the prescriptive requirement and enables the possibility of a trade-off in efficiency for different building elements.

Description of Energy Modelling Software
The software used for the analysis of the building's energy performance is eQUEST Version 3.65. In line with the requirements outlined in ECBC, the software is a program based on the DOE-2.2 simulation engine and has the capabilities to model the following:

- 8760 hours per year
- Hourly variations in occupancy, interior loads, HVAC equipment's and controls, defined separately for weekdays, holidays, and weekends.
- Multiple thermal zones
- Part load performance curves for mechanical equipment
- Airside economizers with integrated control
- Perform design load calculations to determine required HVAC equipment capacities and air and water flow rates under ECBC standards for both proposed case and baseline models.
- Perform simulation using a representative weather file specific to a location

2.2 Building Model Description

Model details:
The project has gone for ECBC compliance through whole building simulation and it has achieved **8 %** energy savings compared to standard ECBC model with an **EPI of 89.5 & EPI ratio of 0.92.** The baseline model stands for a standard benchmark with which the actual case proposed model is compared. The baseline model has the inputs as per ECBC instead of actual as in the proposed case. The model is then simulated by using an appropriate weather file of the project location. As per ECBC guideline, the baseline model is simulated for the four directions based on parametric runs for 0, 90, 180 & 270 degrees. The average of the parametric runs is being taken into consideration for the final energy consumption.

Weather File
The project building is situated in Mohali, Punjab which comes under the composite climate zone. Envelope parameters for the Baseline model have been selected as per the composite climate zone Weather file used for simulation is of Patiala. Patiala is the nearest location from the project and its weather Condition is quite similar to Mohali, Punjab. The same weather file has been used for both Baseline and Proposed models.

2.3 Summary of ECBC Compliance

Mandatory Provisions Under ECBC

- U-Factors and Solar Heat Gain Coefficient
  U-factors are determined for the overall fenestration product (including the sash and frame) by ISO-15099, by an accredited independent laboratory, and labeled and certified by the manufacturer or other responsible party.
- Air Leakage
  Air leakage for glazed swinging entrance doors and revolving doors are not exceeding 5.0 l/s-m^2. Air leakage for other fenestration and doors are not exceeding 2.0 l/s-m^2.
- Building Envelope Sealing
  The project team has sealed, caulk, gasket, or weather-strip the following areas of the enclosed building envelope to minimize air leakage.
- Building orientation and massing
  The geographical North of the building is in the South West of the building

3. Energy Model Parameters- Actual Case

Building Opaque Envelope- Actual Case
The project has a cavity wall with bricks on both sides & a roof without insulation. The project has designed its lighting to maintain maximum LPD of 5.1 W/m^2, which is lower than the ECBC requirement of maximum LPD of 11.2 W/m^2.

Table 2: Opaque envelope specification- Wall & Roof U- value Calculation

Wall- U- value Calcs- Brick Wall					
Material	Thermal Conductivity (W/m. K)	Thickness (m)	R-value (m^2.K/W)	R-value (Btu/hr. ft^2. deg.F)	
External Surface Resistance			0.05	0.284	
Cement Plaster	0.721	0.015	0.021	0.118	PER NBC
Brick Wall	0.811	0.23	0.284	1.61	PER NBC
Air Gap	0.025	0.115	4.6	26.12	https://thermtest.com/materials-database
Brick Wall	0.811	0.115	0.142	0.805	PER NBC
Cement Plaster	0.721	0.015	0.021	0.118	PER NBC
Internal Surface Resistance			0.128	0.727	
Total R- Value (m2.K/W)			**5.245**		
Total U- Value (in Btu/ hr. ft^2 deg. F)			**0.034**		

Roof- U- value Calcs					
Material	Thermal Conductivity (W/m. K)	Thickness(m)	R-value (m^2.K/W)	R-value (Btu/hr. ft^2. deg. F)	
External Surface Resistance			0.039	0.221	
Brick Tile	0.798	0.025	0.0313	0.178	PER NBC
Earthen Mud	0.519	0.075	0.1445	0.821	PER NBC
Mud Fuska	0.519	0.025	0.0482	0.274	PER NBC
RCC Slab	1.58	0.178	0.1127	0.64	PER NBC
Internal Surface Resistance			0.167	0.948	
Total R- Value (m2.K/W)			0.543		
Total R- Value (in Btu)			**3.081**		
Total U- Value (in Btu)			**0.325**		

- **Window wall ratio**

The project has designed minimum fenestration but enough to get adequate daylight and proper ventilation. Overall Window Wall Ratio is coming out to be **19.57%.** The building has also used fins over windows in some directions and some sections of the building to reduce the direct heat gain from the sunlight.

	AVERAGE U-VALUE/WINDOWS (BTU/HR-SQFT-F)	AVERAGE U-VALUE/WALLS (BTU/HR-SQFT-F)	AVERAGE U-VALUE WALLS+WINDOWS (BTU/HR-SQFT-F)	WINDOW AREA (SQFT)	WALL AREA (SQFT)	WINDOW+WALL AREA (SQFT)
NORTH	0.809	0.034	0.262	814.17	1947.99	2762.15
NORTH-EAST	0.812	0.034	0.242	2505.14	6829.12	9334.26
EAST	0.889	0.034	0.099	94.45	1137.40	1231.85
SOUTH-EAST	0.832	0.034	0.121	1081.59	8766.05	9847.65
SOUTH	0.814	0.034	0.210	551.76	1886.79	2438.55
SOUTH-WEST	0.815	0.034	0.182	1844.18	7858.93	9703.11
WEST	0.809	0.034	0.214	811.40	2678.63	3490.03
NORTH-WEST	0.816	0.034	0.176	1358.68	6123.98	7482.66
FLOOR	0.000	0.083	0.083	0.00	6996.84	6996.84
ROOF	0.798	0.295	0.302	371.00	27040.34	27411.34
ALL WALLS	0.816	0.034	0.187	9061.36	37228.89	46290.25
WALLS+ROOFS	0.815	0.144	0.230	9432.36	64269.23	73701.58
UNDERGRND	0.000	0.062	0.062	0.00	18589.36	18589.36
BUILDING	0.815	0.122	0.188	9432.36	89855.43	99287.79

Figure 1: Window Area Details in Each Direction

- **Glazing Recommendation**

Actual CaseThe project team has used a single glazed unit. This has impacted on the energy consumption of the building. The glass used in the building is lesser efficient than the baseline.

Table 3: Glazing Specification

Glazing Assembly	Specification		
Glazing type 1	U- Value	SHGC	VLT
	5.7 W/m^2K	0.85	89%

4. Comfort Systems and Controls- Actual Case

Mandatory ECBC requirements

- Natural Ventilation
  The project team has designed the building following all the necessary provisions of NBC 2016 including the design guidelines for Natural Ventilation.
- Minimum equipment efficiencies
  The project has met all the minimum equipment efficiency norms under ECBC for Unitary AC Systems, Electric Gas Heaters, Ceiling Fans, etc.
- Controls
  The project has given all the necessary controls required for heating and cooling equipment.
- Building HVAC design and systems- Actual Case
  The project is providing cooling in the building through the VRV system. To meet the ECBC requirement, the project building is installed with a Split system of COP 3.65**.** The building will be requiring nearly **217 TR** of cooling.
- Piping and ductwork- Actual Case
  The piping of refrigerant for the split systems has Accoflex W insulation with a minimum R-value of 1.08 Sq. m. K/w or higher.
- Condensers
  The condensers of the Split System are placed at locations such that they are not exposed to direct sunlight and they are free from any obstructions

Lighting

Mandatory requirement

- Automatic Controls
  The project has installed Occupancy sensors in areas like corridors, toilets, treatment rooms, and conference rooms, and Astronomical time switch which will be provided for exterior lighting.

- Lighting power density- Actual Case
  The project has gone for building area method to meet ECBC requirement. The project has used LED lights in all buildings. LPD of 5.91 W/m^2 has been maintained in the building. Lighting Power density Calculation is as given below:

Table 5: Lighting Power Density Calculations

Lighting Power Density Calculations- Actual Case				
Floor Name	Fixture Type & Wattage			Total Wattage
	LED (W) (30Wx4)	Tube light (W) (18Wx4)	Ceiling Light (9W)	
	120	72	9	
Ground Floor	46	71	27	10875
First Floor	42	66	18	9954
Second Floor	44	63	18	9978
Third Floor	9	45		4320
Total Wattage (W)				35127
Total Building Area (m^2)				6884.3
Lighting Power Density (W/m^2)-Actual Case				5.1
Lighting Power Density (W/m^2)- Baseline Case				11.2

- Exterior lighting detail

For now, the exterior lighting hasn't been finalized yet. Thereby a total load of 9.56 kW has been considered in both the cases (Proposed as well as baseline), Thereby no savings have been claimed due to exterior lighting.

- Exterior lighting control

Astronomical time switch will be provided for automatic control of exterior lighting.

Electrical

- Transformer
  BEE 5-star rated transformers will be installed to maintain the power losses as per table 8.1 at 50% and 100% loading.
- Motors (type, efficiency)
  The motors better than IS 12615 rated motors shall be installed.
- Check metering and monitoring
  The project has installed smart meters that can display kVA, kWh, PF, current, voltage, THD.
- Power factor correction
  Automatic Power Factor Corrector (APFC) will be integrated with the transformer to maintain the power factor close to unity. The tentative spec sheet of the proposed APFCs is placed at Annexure-7
- Power distribution system
  The project will install cables of adequate size to maintain the internal power distribution losses at max 1%.
- Equipment:
  Equipment details are not provided thereby it has been assumed as 0.5 W/ft^2. It has been kept as same in both the proposed as well as the baseline case. The running schedules for the proposed as well as a baseline are also the same in both the cases.

Energy Model Parameters- Baseline Case

Building Opaque Envelope- Baseline Case

Table 6: Summary of the Building Components

Envelope Parameter's	Proposed Case	Baseline Case
Roof Assembly	**0. Btu/h.ft^2.degF** Or **1.845 W/m^{2}K**	U-factor of **0.083 Btu/h.ft^2.degF.** Or **0.47 W/m^{2}K**
Wall Assembly	**0.034 Btu/h.ft^2.degF** Or **0.193 W/m^{2}K**	U-factor of **0.149 Btu/h.ft^2.degF** Or **0.85 W/m^{2}K**
Glass Construction (SHGC)	Single Glazed glass with a SHGC of **0.85**	SHGC Glass North- 0.50 SHGC Glass- Non-North- 0.27 SHGC Glass- Skylight- 0.35
Glass Construction U- value	U- factor **0.19 Btu/h.ft^2.degF.** Or **5.7 W/m^2 K**	U- factor **0.53 Btu/h.ft^2.degF.** Or **3 W/m^2 K- For all the Façade** Skylight U- Factor – **4.25W/m^2 K** **Or** **0.75Btu/h.ft^2.degF.**
Skylight	1.3%	1.3%
Window Wall Ratio (WWR)	19.57%	19.57%
Lighting Power Density	5.10 W/m^2 or 0.47 W/ft^2	11.2 W/m^2 or 1.04 W/ft^2
HVAC System Type	Split Systems-217 TR	Split Systems-212 TR
HVAC System COP	3.65 COP (Certificate Attached)	2.8 & 3.29 COP (calculation provided)
Ventilation & Fan (kW)	18.98 kW	13.8 kW

Lighting- Baseline Case

The Baseline case has considered lighting power density as per Table 6-1 of Section 6.3.2 of ECBC. The lighting power density of the baseline case has been taken as a school from Table 6-1 which is 11.2 W/m^2 or 1.04 W/ft^2.

Energy Consumption Analysis

Proposed Case

The Proposed model is designed in eQUEST 3.65 with its various parameters like Occupancy, lighting, HVAC. HVAC is modeled per mechanical floor plans. The total annual Electric Energy Consumption for the proposed case is **615.52*1000 kWh. The energy consumption of different component is as given below:**

Table 8: Proposed Case Energy Consumption (kWh*1000)

Energy Consumption -Proposed Case (kWh*1000)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.89	3.53	13.58	27.71	42.13	49.05	45.17	42.95	33.73	20.14	8.92	2.03	289.85
Space Heat	1.17	0.2	0	0	0	0	0	0	0	0	0.05	0.36	1.77
HP Supp.	0.02	0	0	0	0	0	0	0	0	0	0	0	0.02
Vent. Fans	4.42	4.03	5.55	7.17	8.83	9.68	9.41	9.19	7.58	5.94	4.45	4.3	80.55
Ext. Usage	4.59	4.15	4.59	4.44	4.59	4.44	4.59	4.59	4.44	4.59	4.44	4.59	54.07
Misc. Equip.	8.08	7.42	8.36	8.32	8.36	8.04	8.36	8.63	7.77	8.36	7.77	8.08	97.55
Area Lights	7.6	6.97	7.86	7.82	7.86	7.56	7.86	8.12	7.3	7.86	7.3	7.6	91.7
Total	26.77	26.3	39.94	55.47	71.77	78.79	75.38	73.49	60.83	46.89	32.93	26.97	615.52

Baseline Case

The Baseline case model is strictly by the ECBC "Whole Building Performance Method". Based on the energy simulation results, it is observed that the average annual electric consumption is **672.504* 1000 kWh.**

The Baseline Case consumption of all the four degrees are as given below:

Table 9: Baseline Case Energy Consumption (kWh*10

Energy Consumption -Baseline Case (kWh*1000)- Average of all rotations													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0.3	1.3	6.9	19.6	39.0	51.2	46.4	43.4	32.9	15.3	4.2	0.7	261.1
Space Heat	1.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.6
HP Supp.	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0
Vent. Fans	3.0	2.8	3.7	5.0	6.1	6.6	6.4	6.3	5.2	4.1	3.1	3.0	55.2
Ext. Usage	4.6	4.2	4.6	4.4	4.6	4.4	4.6	4.6	4.4	4.6	4.4	4.6	54.1
Misc. Equip.	8.1	7.4	8.4	8.3	8.4	8.0	8.4	8.6	7.8	8.4	7.8	8.1	97.6
Area Lights	16.8	15.4	17.4	17.3	17.4	16.7	17.4	18.0	16.2	17.4	16.2	16.8	202.9
Total	33.8	31.3	40.9	54.7	75.4	87.0	83.1	80.9	66.4	49.7	35.7	33.6	672.5

Savings Calculations :

Table 10: Savings Summary

Energy Savings Summary- Wisdom Ark School								
End-Use	Proposed Building Cost ($)				Baseline Building Cost ($)			Percentage Saving
	Energy Type	Energy	Peak	Cost $/Year	Energy	Peak	Cost $/Year	Energy
		kWh	kW	$	kWh	KW	$	%
Space Cool	Electricity	289852	170.481	2898520	261147.5	236.813	2611475	-11%
Space Heat	Electricity	1770	61.297	17700	1592.5	67.408	15925	-11%
HP Supp.	Electricity	17	5.296	170	0	0	0	0%
Vent. Fans	Electricity	80552	18.987	805520	55220	13.779	552200	-46%
Ext. Usage	Electricity	54075	8.602	540750	54075	8.602	540750	0%
Misc. Equip.	Electricity	97555	30.147	975550	97555	30.1	975550	0%
Area Lights	Electricity	91701	28.339	917010	202914	62.707	2029140	55%
Total		615522	323.149	6155220	672504	419.409	6725040	8%
Area (m2)	6884.3				6884.3			
EPI (kWh/year/m2)	89.4				97.7			
EPI Ratio							**0.92**	
Compliance Achieved							**ECBC Complaint Building**	

Energy Cost Savings: Energy cost has been taken as ₹ 10/kWh of electrical consumption for both the proposed as well as the baseline case

Conclusion:

Graphical Representation:

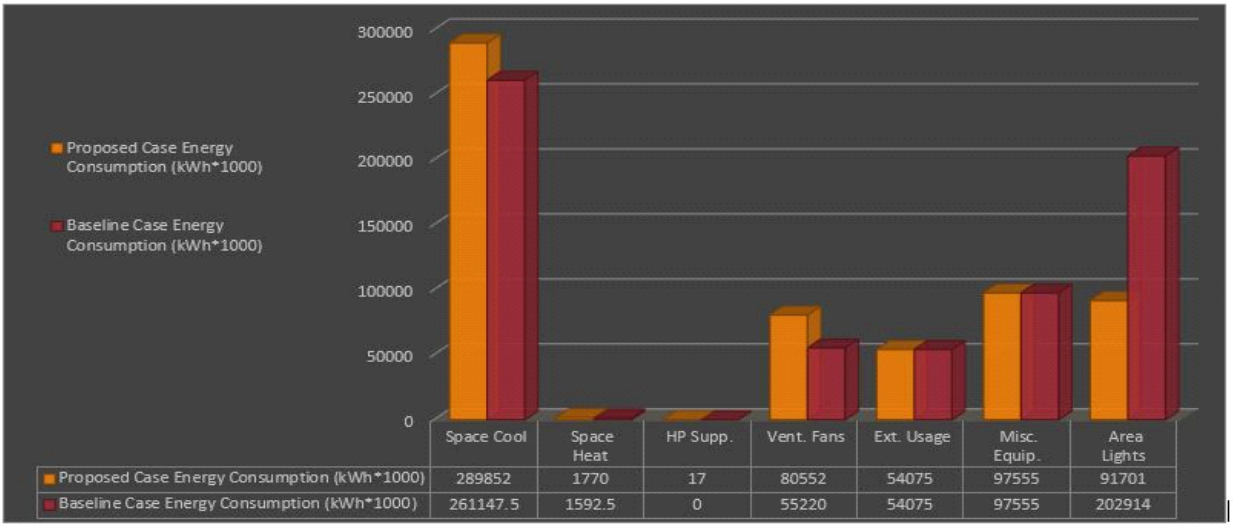

Figure 4: Graphical Representation of Energy Consumption

The total energy consumption of the baseline case is **672,504 kWh** whereas the total energy consumption of the proposed case **is 615,522 kWh**. Which leads to a total savings of around **8%** for the project building. The project has gone for ECBC compliance through whole building simulation and it has achieved 8 % energy savings compared to standard ECBC model with an EPI of 89.5 & EPI ratio of 0.92.

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