ENERGY CONSERVATION BUILDING CODE (ECBC) COMPLIANCE AND BEYOND A PILOT STUDY

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मालवीय राष्ट्रीय प्रौद्योगिकी संस्थान जयपुर

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EXECUTIVE SUMMARY

Ever since the launch of Energy Conservation Building Code in India, in the year 2007, efforts are being made to develop enabling environment for its effective implementation in the country. Due to consistent efforts by Bureau of Energy Efficiency and other bilateral projects, especially the USAID supported ECO-III project; awareness about promoting energy efficiency in buildings got onto the agenda of different state governments in the country. In the year 2010, Rajasthan took up the initiative and after following the process of forming technical committee for adapting ECBC to state, stakeholder consultation and other legal processes, notification for Energy Conservation Building Directives was released in the year 2011. Rajasthan ECBD is not significantly different from the parent code: ECBC. Ever since then, need of doing a pilot project was being felt through which the process and most importantly learnings would be documented for the benefit of larger mass of professionals.

Malaviya National Institute of Technology Jaipur, is a Government of India funded Institute, established in the year 1963, declared as an Institute of National Importance through an Act of Parliament. The Institutetook this task of attempting abuilding on pilot basis for ECBC compliance. The institute had an advantage of having a combination of civil, architecture, mechanical, electrical engineering departments as well as the Centre of Energy and Environment under one roof to support this endeavour.

Soon after the ECBC was adopted in the state of Rajasthan, project of adding one floor on one of the existing single storey buildings called ‘Design Centre’ (now renamed as ‘PrabhaBhawan’), was being initiated. Quick evaluation of loads revealed that the building was falling under the scope of ECBC/ECBD after addition of one floor; hence this was selected as candidate building for doing the pilot. Later through an internal decision, addition of one more floor and refurbishment of existing ground floor was planned, that made the case unique in its nature as pilot.

Decisions about selection of materials, systems, components, etc. have been taken considering code compliance through whole building performance. Major reason behind it was flexibility in decision making, especially considering factors such as cost, feasibility, restrictions due to existing floor. Encouraged by the energy saving potential, the pilot project for ECBC got extended to showcase efficiency beyond ECBC. The results have shown that the new building with all energy efficiency measures undertaken is likely to be 30% more efficient over the Energy Conservation building Code.

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DISCLAIMER

This project report covers the process of development of the Prabha Bhawan Building (previously known as Design Centre)at MNIT, Jaipur using ECBC as guidelines. The facts and information used in this report are as per the design time informaiton. It should be noted that with passage of time, the function, occupant loads etc. will evolve or might change as compared to those considered for development of this report, which in turn might change the increase or decrease the energy savings.

INTRODUCTION

Energy is the vital force fuelling the life on earth. It governs every aspect of life, from running the machines to the flick of a simple switch. With the threat of energy crisis looming, various strategies to conserve the energy, harness renewable energy from every possible source etc. are worked upon. The Energy Conservation Building Code is one of such initiatives. ECBC was developed as per one of the mandates of Bureau of Energy Efficiency under the Energy Conservation Act, 2001; which empowers the Central Government to define norms and standards of energy consumption.

The idea of developing and monitoring a project based on ECBC compliance took birth from the interest in availing various benefits of such a building. ECBC compliant buildingsare likely to have less operating costs of buildings, less connected load, reduced demand charges, reduced capacity of transformer, panel, circuit breaker etc.Acceptable payback/IRR, for several energy conservation measures (ECMs)and necessity of showcasing use of few technologies, motivated to go beyond ECBC. However, the main driving force behind the project was the idea of learning by doing, capacity building and the showcasing of results as there is no better way than leading by example.

The Prabha Bhawan (Previously known as Design Centre) is training cum office centre built for the students and staff ofMalaviya Institute of Technology Jaipur, Rajasthan. It used to be a single storey academic office cum laboratory building. Primarily it was used for academic and support office purpose only. The construction of Prabha Bhawan (Previously known as Design Centre) was extended to accommodate additional two floors to house computer centre, and to provide training space for events such as Executive Development Programs, Seminar, and Workshops.

Figure 1 : Malaviya National Institute of Technology, Jaipur

Figure 2 (a, b): Satellite Images of Prabha Bhawan (previously known as Design Centre) Before and After the Project

Currently, Prabha Bhawan (Previously known as Design Centre)houses high end computer and data centre and computer based design labs catering to all the graduate, post graduate students and research scholars of the Institute as well as outside world.

CONTEXT

Rajasthan, the largest state of India by area is a thriving tourist destination with abundance of solar energy. The major portion of the state falls under hot and dry climate making energy efficiency an important component as the cooling loads are high. Rajasthan Renewable Energy Corporation Limited, the designated agency of Bureau of Energy Efficiency for enforcement and provision of Energy Conservation Act of 2001, has beentaking state level initiatives related to energy conservation in the state. Through one of RRECL's initiative with a collaborative and consultative process, the state approved the contents of ECBC as ECBD incorporating few minor additional requirements. In 2010, the Government of Rajasthan published a directive mandating compliance of ECBD in commercial buildings of the state.

Malaviya National Institute of Technology, Jaipur helped in the facilitation of the same through technical inputs and clarifications when the code was being adopted by the state government. Even after release of notification, and as experienced during the 10 training programs conducted by MNIT on ECBC for architects, designers, government officials of the state, several queries were prevailing about implementation of the CODE in buildings. Nearly at the same time, the project of Prabha Bhawan (Previously known as Design Centre) was getting initiated and therefore, it was decided to showcasing the benefits of ECBC and its compliance methods through this project.

The project was initiated with one partially conditioned single floor block of approx. 4000 m^2area. Initially, only one floor was to be added on the existing block. As the project progressed, the decision of adding one more floor was taken. Subsequently, decision of major retrofitting of ground floor was taken. Currently, half portion of the first floor of building is functional. The ground floor of the building is at finishing stage. The top floor is ready for furnishing.

Figure 3: Front View of Prabha Bhawan (previously known as Design Centre)

THE SURROUNDING PARAMETERS

Certain parameters are needed to be understood for getting the clear background of the project. Location of the project with respect to the surroundings, the climatic conditions and other similar influencing factors are discussed in this section.

PHYSICAL FACTORS

Prabha Bhawan (Previously known as Design Centre) lies nearly 200m from the main entrance of MNIT Jaipur, on the Northern side of the Canteen "Annapurna". It is not having any nearby building casting shadow on it or blocking wind and daylight into the building. A secondary road on the North-eastern side connects it to the canteen and the computer engineering and electronics departments.

Figure 4: Latest Satellite Image of Prabha Bhawan (Previously known as Design Centre) and the surroundings

Table 1: Project Summary

Location	Malaviya Institute of Technology, Jaipur, Rajasthan, India
Building Type	Office cum computer Centre
Building operation	Monday to Friday (8:00 am to 8:00 pm)
Orientation	True North
Total floors	Three (G+2)
Carpet Area	11306 Sq.Meters
Conditioned area	9959 Sq.Meters
Unconditioned area	1347 Sq.Meters
WWR	27%

CLIMATIC CONDITIONS

As per climatic classification of India, the project lies in the composite climate zone. The intensity of solar radiation is very high in summer with diffuse radiation amounting to a small fraction of the total. In monsoon season, the intensity of direct solar radiation is low with predominantly diffuse radiation. In this particular climate zone, the maximum day time temperature in summers is in the range of 32°-44° C, and night time values are from 27°-32° C. In winter, the values are between 10°-25° C during the day and 4°-10° C at night. The relative humidity is about 20-25% in dry periods and 55-95% in the monsoon season.

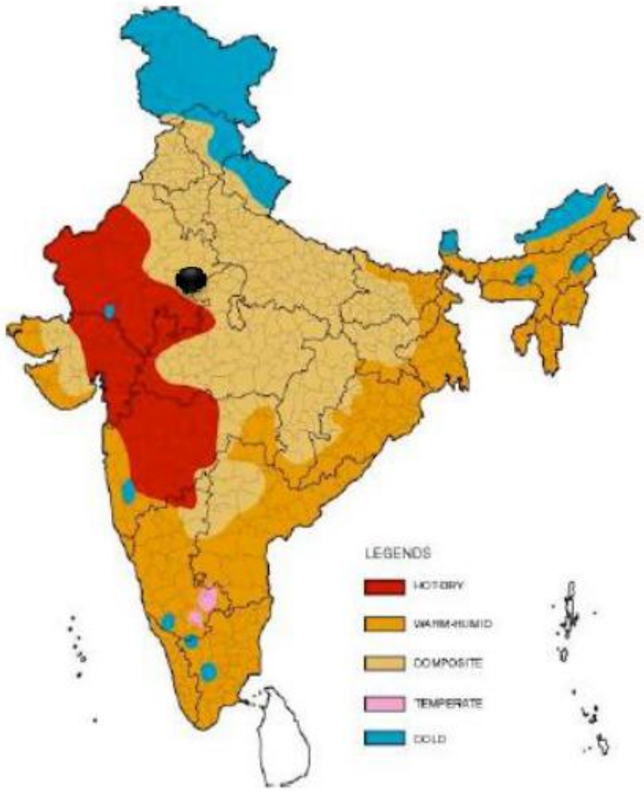
Latitude:26.5° N

Longitude:75.5 ° E

Elevation : 390 Metre

CDD : 5732, 10° C Base

HDD : 141, 18° C Base



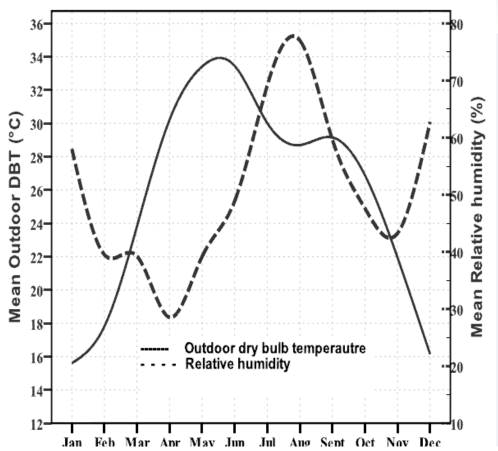


Figure 6 : Monthly Variation in Outdoor DBT and RH in Jaipur City

Figure 5 : Climatic Zones of India (NBC 2005)

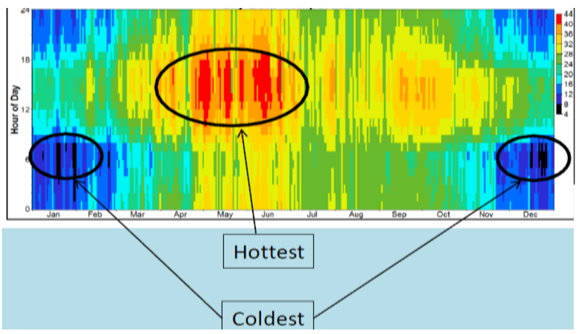


Figure 7 : Dry Bulb Temperature (°C)

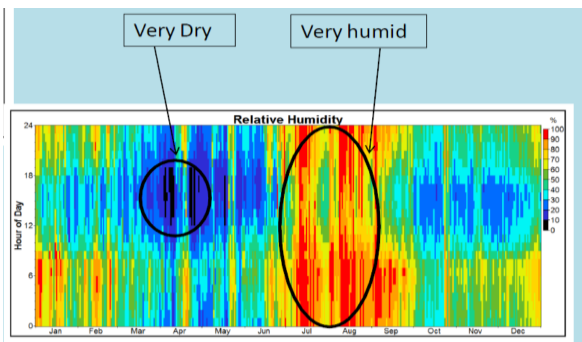


Figure 8 : Relative Humidity (%)

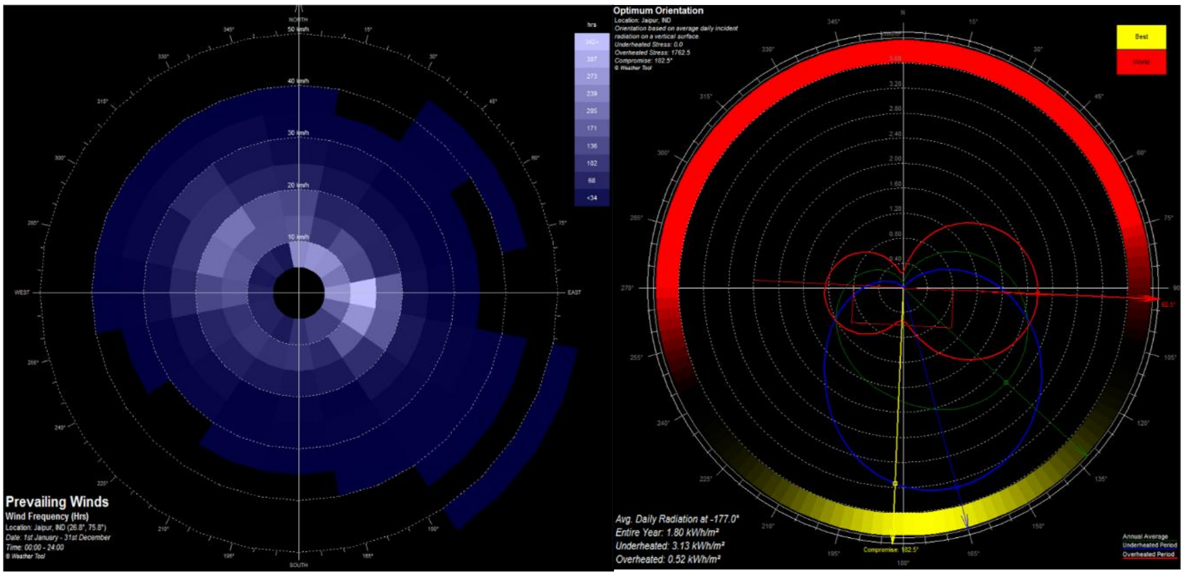


Figure 9 : Annual Wind Rose and optimum orientation schematic for Jaipur (Generated from Autodesk Ecotect Analysis 2011)

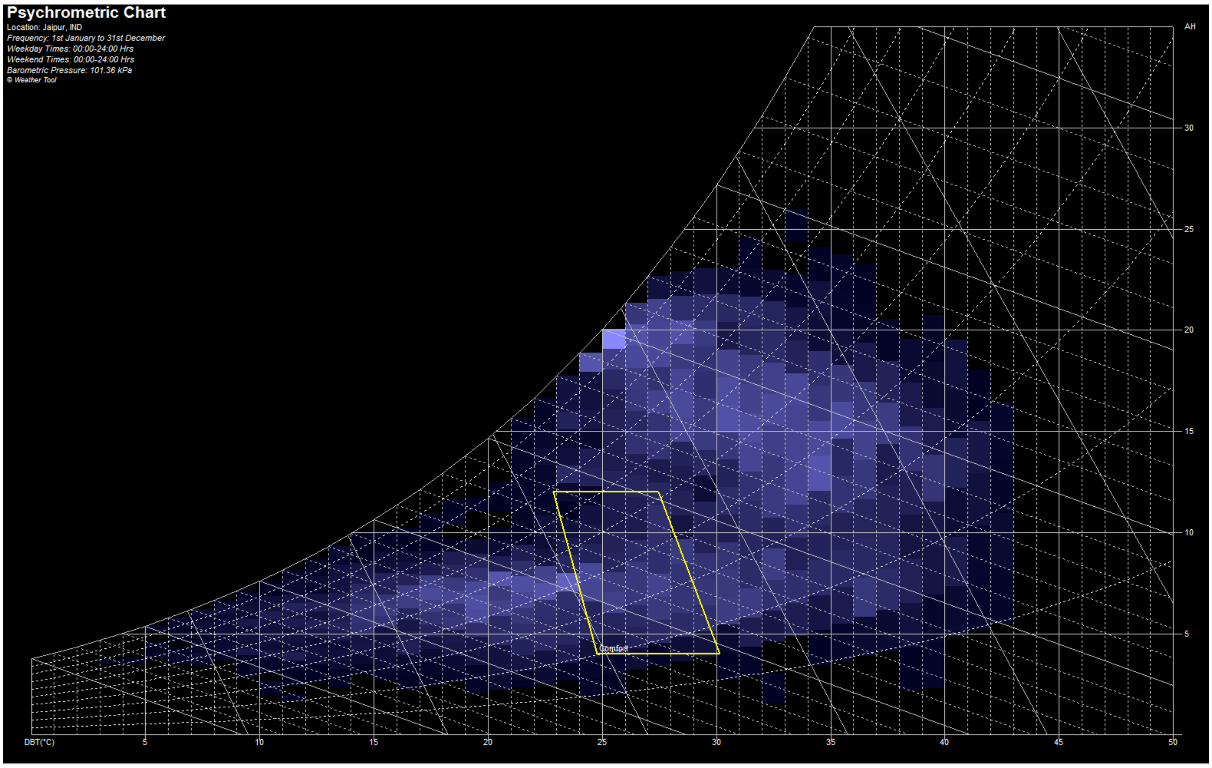


Figure 10: Psychometric Chart (Generated from Autodesk Ecotect Analysis 2011)

ENERGY EFFICIENCY CONCEPTS/ APPROACHES

The project was put on the path of ECBC compliance with the approach discussed further in this topic. Architectural initiatives were considered first of all as the approach towards energy conservation must be from inside out. The design features are the most important aspects to be focused upon from the beginning.

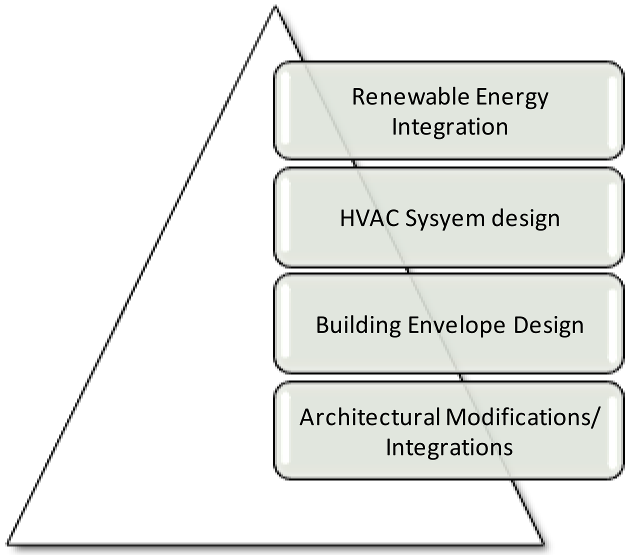


Figure 11: The Energy Efficiency Target for a built environment

Then the building envelope was modified to decrease the cooling load of the building to the best possible extent but at the same time daylight design was weighed along too. Thirdly the HVAC system was planned judiciously as the building has a highly fluctuating occupancy between very lean to full occupancy. Renewable energy system was integrated into the building to further reduce electricity drawn from the grid.

Since the ground floor of the building was already existing prior to beginning of this project, integrating the above floors in smooth manner, without changing architectural features, while achieving high energy efficiency level, was a challenge throughout.

ECBC APPLICABILITY CHECK AND COMPLIANCE ROUTE

The building is of Non-Residential type with a connected load (estimated) of more than 100 kW. It's not a new building but addition of two floors and change of fenestration, lighting and HVAC system of ground floor bring it under code coverage.

The Code compliance requirements can be met by two alternative methods specified in the Code:

Prescriptive Method: that specifies prescribed minimum energy efficiency parameter for various components and systems of the proposed buildings.
Whole Building Performance Method: It is more complex for implementation, requires simulation skills, but offers considerable design flexibility and opportunity to choose cost effective options and dropping those that are not mandatory requirements and are not cost effective. It allows for the Code compliance to be achieved by optimizing the energy usage in various building components and systems, envelope, HVAC, lighting and other systems; in order to achieve cost or any other objective such as aesthetics etc.

In case of this project, Whole Building Simulation route was selected for ECBC compliance instead of prescriptive route, due to the following reasons:

Flexibility in selection of elements and systems.

Presence of non – standard design of shading fins that don't have shading 'M' factor in the prescriptive route

Higher efficiency of lighting and HVAC systems as compared to prescriptive route, advantage of which cannot be taken for relaxation in specifications of other components through prescriptive route even using Trade-off method.

Hourly energy simulation tool "eQUEST (version 3-65)" is used for performing modeling and simulation of Prabha Bhawan (Previously known as Design Centre) .

CONCEPTS AND APPROACH TOWARDS ENERGY EFFICIENCY

The deisgn is courtyard based with office spaces, computer centres, meeting rooms, seminar rooms and auditoriums of small capactiy arranged around the same. Floor plans of ground and second floor (top floor) of the Prabha Bhawan (Previously known as Design Centre) are presented in Figure 14 and Figure 16 respectively. The ground floor is designed to provide office spaces, computer labs and auditoriums of small capacity and it has been renovated completely with insulation to the wall and roof, energy efficient lights as well as lighting fixtures and retrofitting of energy efficient air-conditioning systems. First and second floors are designed to provide spaces for office, large capacity meething halls and computer labs for training/workshop purposes.

BUILDING LAYOUT AND FEATURES

As the project is located in composite climate, a conscious effort was made to integrate all the strategies in designing built environment (Figure 13).

COURTYARD DESIGN:

The project is based on the tried and tested courtyard design which was consciously retained as it provides host of advantages to the building. The courtyard provides a vent out for the hot air and may be used as sit out. It provides exposure to sky to the areas around it so the waiting areas are placed along the edges of the courtyard. It has also been very useful in ensuring ample daylight in the spaces around the courtyard, that otherwise would have been deprived from daylight due to their distance from outer periphery.

Figure 12 : Ramp on the western side

SELF-SHADING FEATURES:

A ramp, that was necessary for facilitating differently able persons, is designed on the west side of building in such a way that it casts a shadow on one side on the west facade, thus decreasing the incidence of solar radiation on the facade. This ramp was having few operable windows to ensure that there is no undue heat accumulation in the ramp space.

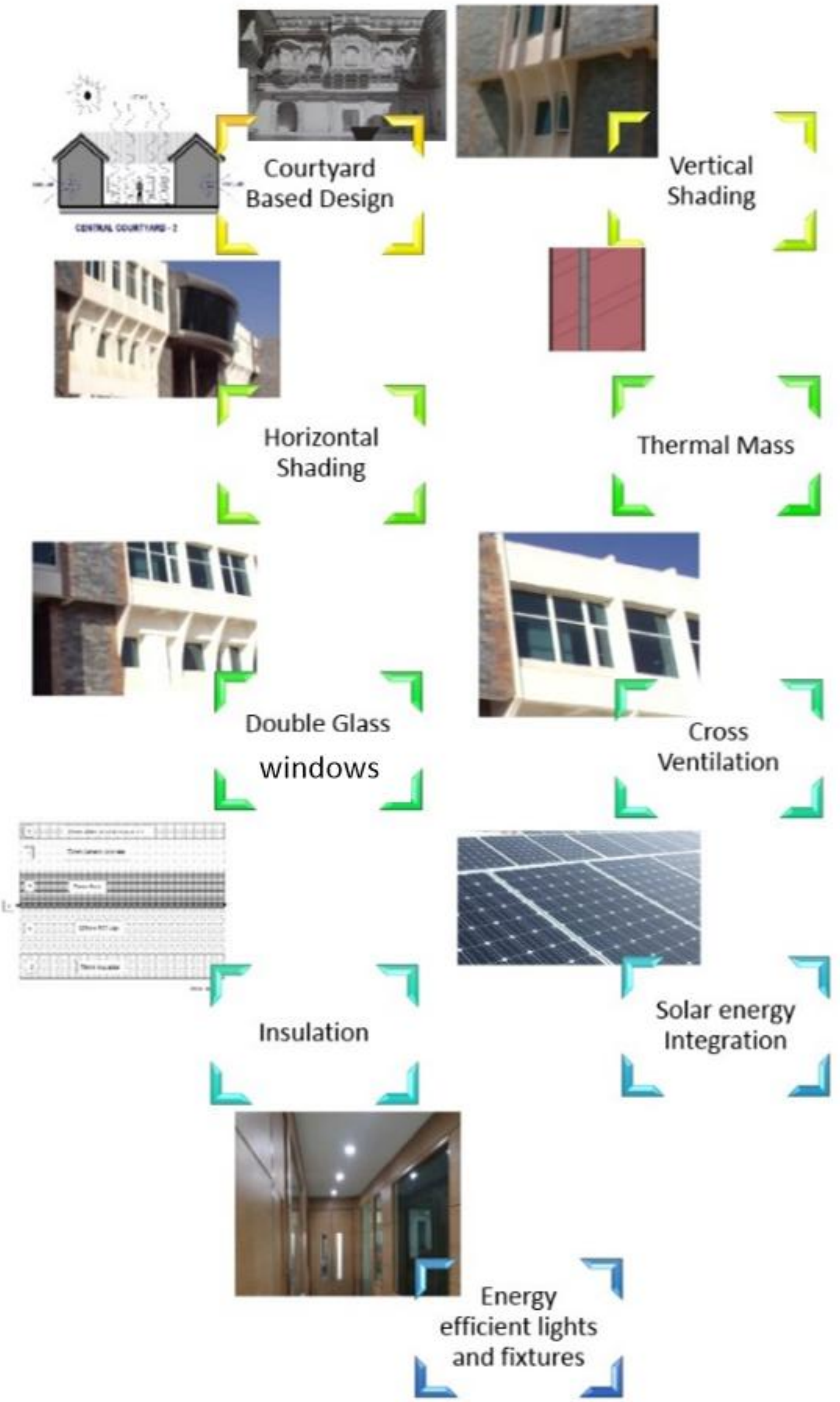


Figure 13 : Building Strategies for composite climate

Similarly the projected first floor serves as horizontal shading on the ground floor, besides providing increased floor area. Further, projected entrance was designed to enhance the self-shading effect.

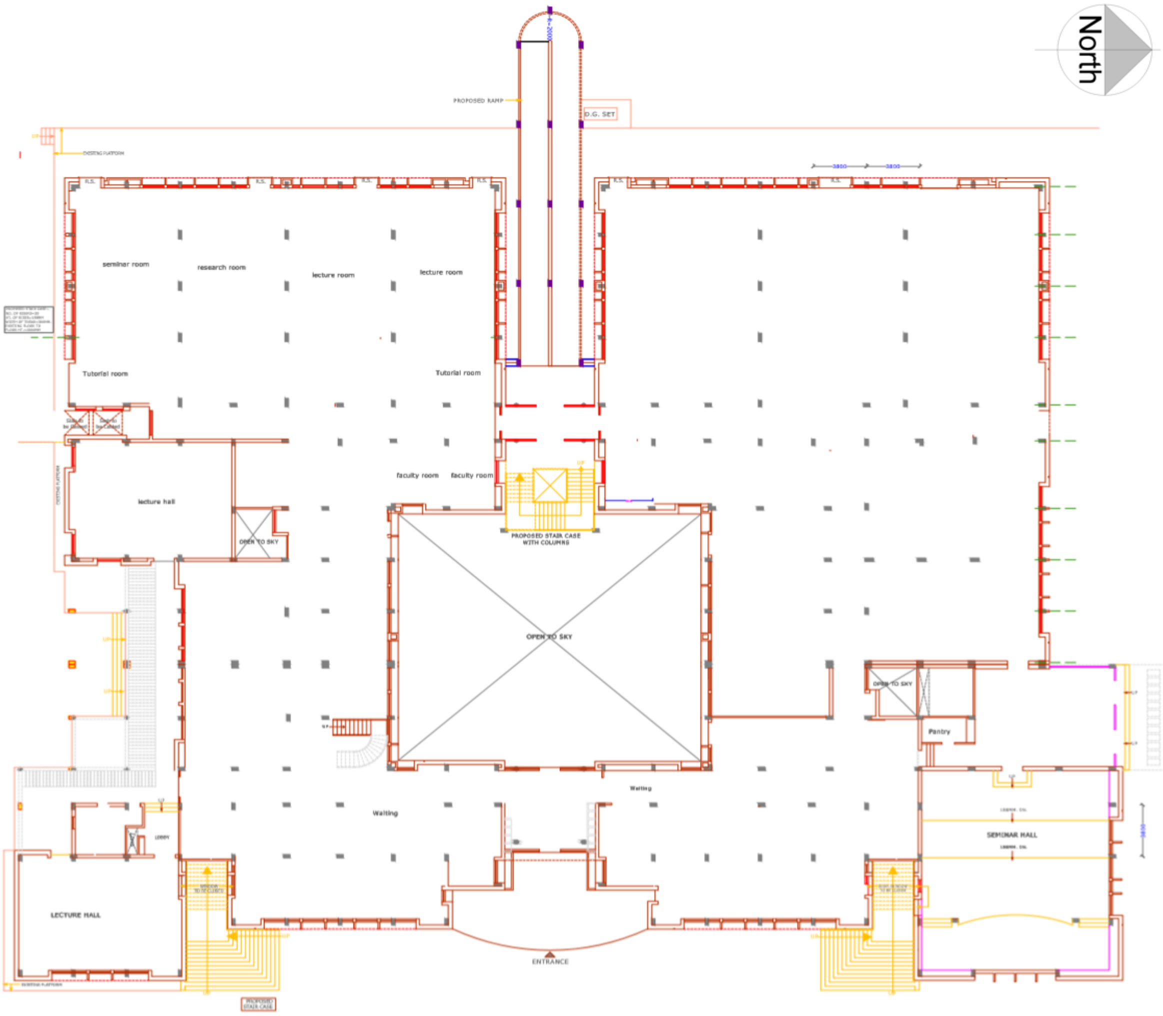


Figure 14 : Ground Floor Plan

Figure 15 : Projected main entrance and the curved vertical fins

VERTICAL FINS:

The existing vertical fins were modified to handle the low morning and evening sun during summer. The curved fins on the first floors are used to architecturally integrate the extended second floor with the ground floor. The sloped glazing of entrance and building contour are designed with self-shading features. Further, the projected entrance was designed to enhance the self-shading effect.

BUFFER SPACES:

The staircases, corridors and facility areas were consciously planned on the southern side of building so as to act buffer zones and to protect entry of heat in the spaces towards southern side of building.

PARTIALLY OPENABLE WINDOWS:

The building is designed to be used in mixed mode operation to utilise natural ventilation as much as possible when ambient conditions are acceptable. For this purpose, one third of window area is kept operable. Most of the windows have three vertical partitions, out of which one is operable. It is expected that occupants would first try to regulate their comfort through opening windows during moderate season, before demanding for air-conditioning. Major architectural features of building that lead to its energy efficiency are marked in Figure 13.

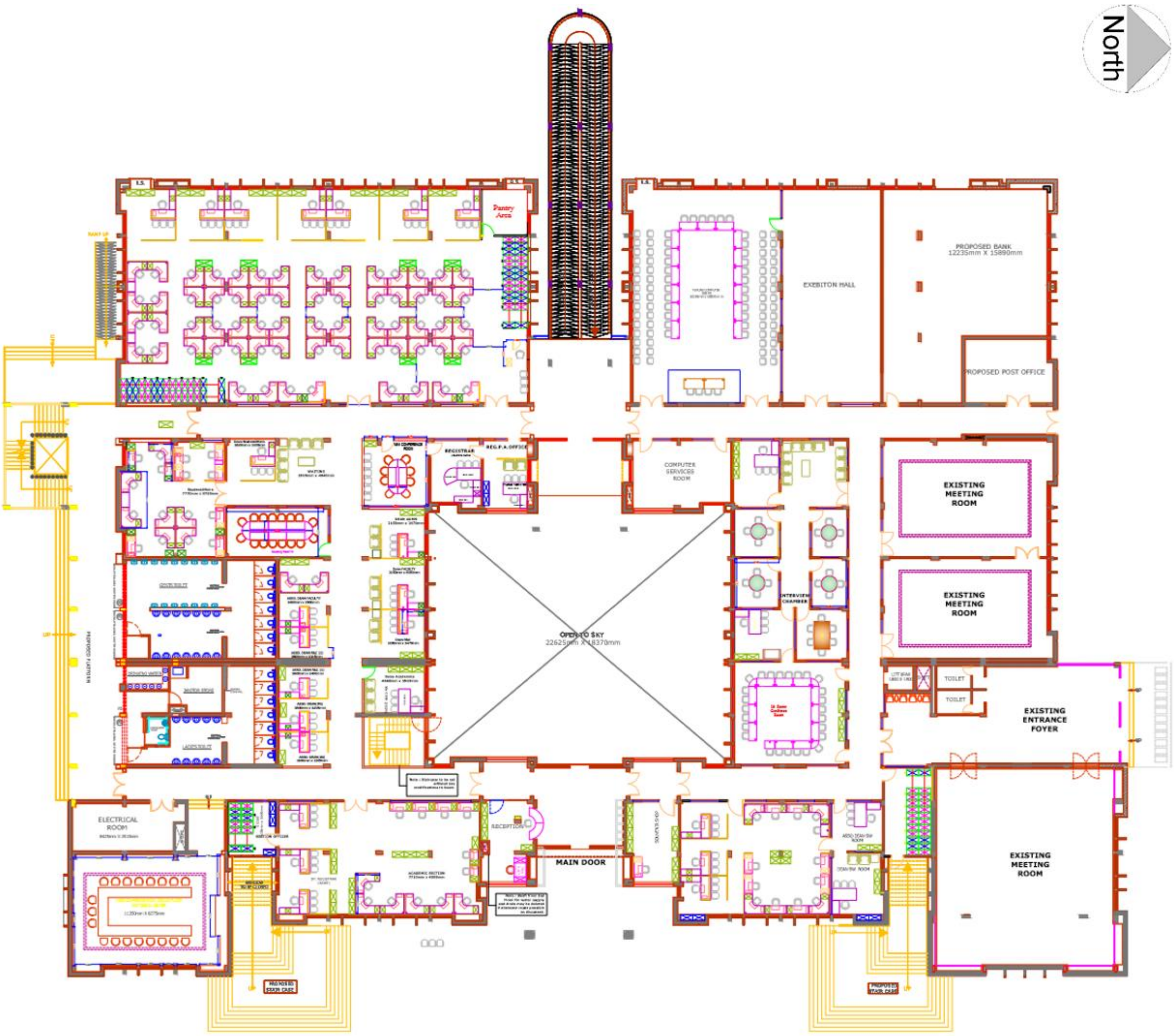


Figure 16 : First Floor Plan

ENVELOPE DESIGN

The building envelope protects the interiors from the harsh summer heat and the cold desert like winters. The properties and the structure of the same play a major role and that was a core issue of Prabha Bhawan (Previously known as Design Centre)   building

Figure 17 : West Side Elevation

Figure 18 : South Side Elevation

Figure 19 : East Side Elevation

Figure 20 : North Side Elevation

GLAZING:

Glazing in hot & dry as well as composite zones is an element to be designed with utmost care as it can easily let in the harsh heat with the much needed light. Keeping this in mind a low SHGC glass was selected which cut down the heat load to a great extent.

Usually, in large number of low SHRC glazing solutions available, reduction in SHGC also results into reduction in Visible Light Transmittance (VLT). In case of this building, selection was consciously made for high VLT with low SHGC. Help of daylight simulation and energy simulation software was taken for arriving at this decision.

eQUEST model was used for examining cost effectiveness of various glazing solutions. Besides energy savings during operation, reduction in tonnage of air-conditioning due to different energy saving glazing was also considered for examining financial viability of any case.

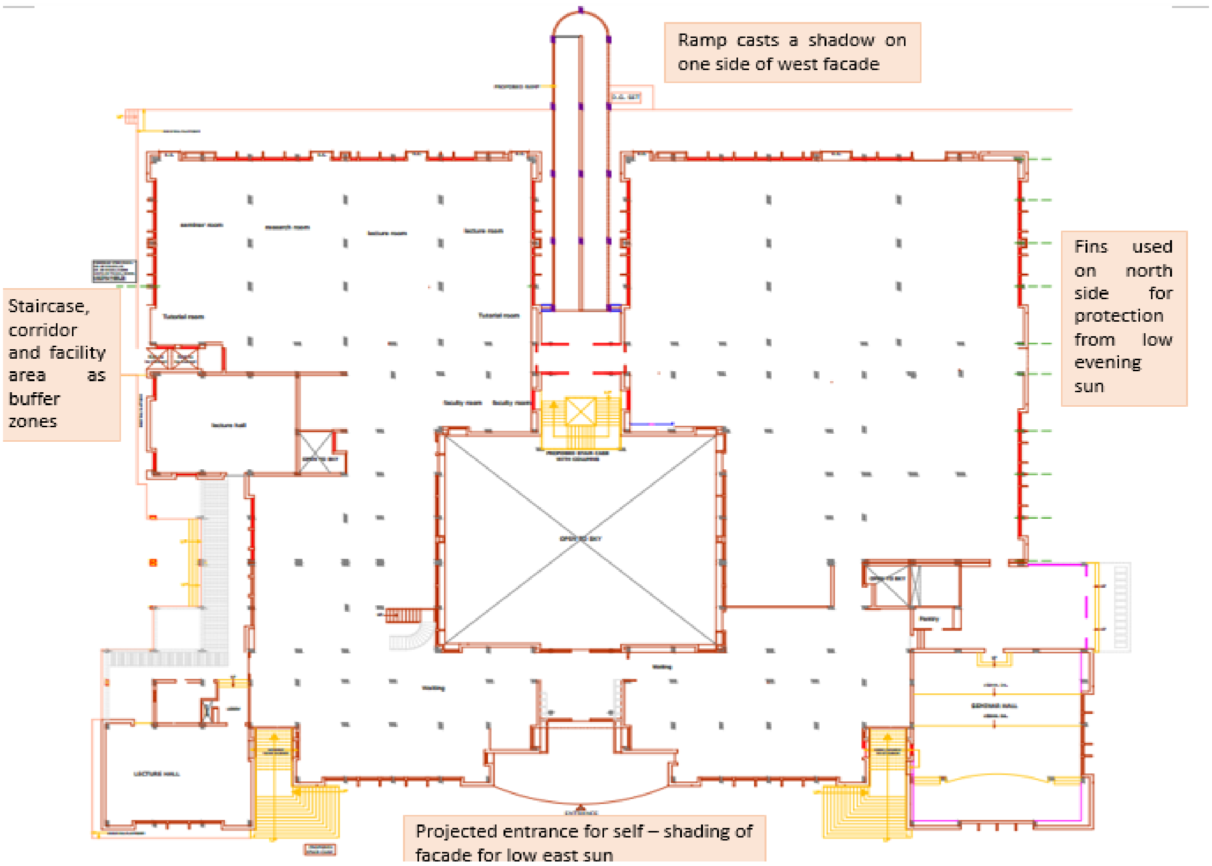


Figure 21 : Architectural Features and their climate response

Care was taken for examining these cases with and without dimmable lighting fixtures. It was important to consider glazing selection along with lighting design since decision about investing in high VLT glass and dimmable ballast are interlinked and should not be taken in isolation. If dimmable lighting fixtures are not selected, there is relatively less incentive in selecting high VLT glass.

After the analysis and matching with product catalogues of suppliers, following specifications of glazing were decided:

U-value: **1.9 W/m^2°C**	SHGC: **0.28**	VLT: **0.39**

Some specifications recommended for use are not 'theoretical ideal' values, since they were required to be matched with nearest product available in the market.

It may be noted that SHGC of the glazing is higher than the prescriptive requirement whereas the U-value is lower. Higher SHGC was deliberately chosen due to two reasons:

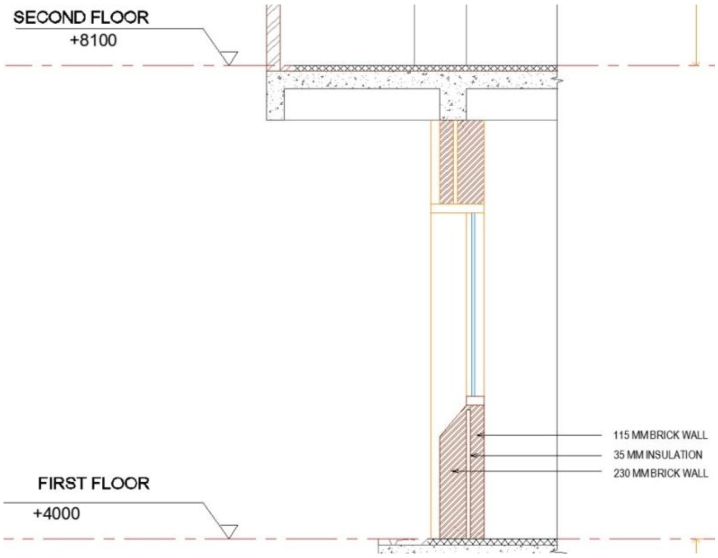


Figure 22 : Wall - Section

Due to presence of fins and self-shading features, effective SHGC of glazing is going to be somewhat lower. Hence, practically the glazing would not behave inferior than the code.

Higher SHGC means higher VLT which is good for daylight

Cost of glazing with higher SHGC is lower, making the solution financially viable.

WALL:

The existing stone masonry of Ground floor could not be continued on first and second floors due to limited availability of stone. However, the concept of using thermal mass was retained on the first and second floors too. For achieving this, an innovative section was worked out, that also addressed the issue of placing insulation on wall. Section of the wall on first and second floor is given in Figure 22.

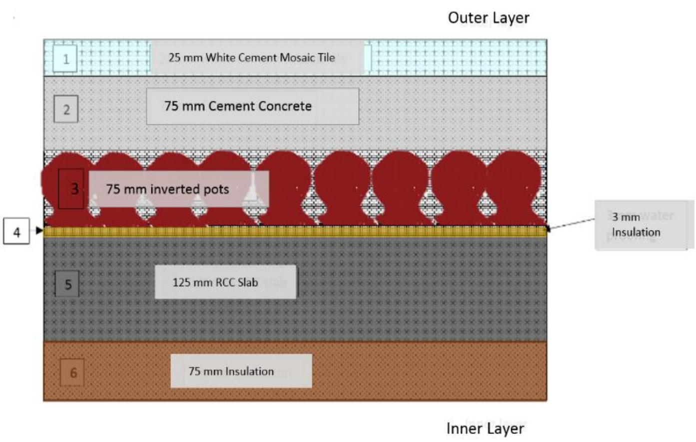


Figure 23 : Typical roof section

Consciously, the U-value of wall was not matched with that of prescriptive requirements of ECBC due to financial reasons. Putting more insulation was not giving energy saving in acceptable proportions, besides resulting into reduction in carpet area available for active use. The U-value of wall section was kept as 0.72 W/m^{2}K.

ROOF:

Although over-deck insulation is likely to give more energy saving as compared to underdeck, the later was chosen due to the risk of damage to water proofing in case of over deck. Although several manufacturers of insulation also extend their services as applicators giving some warranty for water proofing, due to lack of confidence of executing agency for using over deck insulation, it was not chosen. Similar to the decision about wall, amount of insulation and details of roof section werefinalised on the basis of simulation based payback analysis, including cost of avoided tonnage. The roof U- value of 0.35, which is even lower than the code requirements through prescriptive route was chosen. Section of the roof is as shown in figure 23.

To summarize, the building envelope design got evolved in the following manner:

Table 2 : Building Envelope Design and reasons

Element	Material / Type	Reasons behind the choice
Roof	RCC with underdeck XPS insulation and over - deck inverted earth pots	To reduce the heat gain from the roof top
Wall	Brick with XPS	To maintain the high thermal mass : XPS, sandwiched between the wall layers
Windows	Double Glazed low heat gain high visible transmittance glass with UPVC Frames	To reduce heat gain through conduction, direct heat gain through solar radiation
Shading Devices	Existing Vertical fins, redesigned for architectural integration and shading	A conscious decision to retain the fins and work on increasing their effectiveness as they provide the much needed shade from the low sun.

LIGHTING DESIGN

Lighting design of any building has 2 components: Natural light and artificial light. Daylight can be understood as the diffused light from a wholly overcast sky and should be considered an integral part of any building. Proper daylighting can increase productivity, decrease sick time and even increase sales. It has two general benefits: Improves the quality of light in a space, Reduces the amount of electrical light required.

It provides tremendous psycological benefits to building occupants and reduces the energy laod of the building to a great extent. The architectural design and the finishes of the building must be the first and foremost tier of design to increase and enhance daylight in the building. Then the fenestration design, glass selection and lastly an efficient artificial lighting layout.

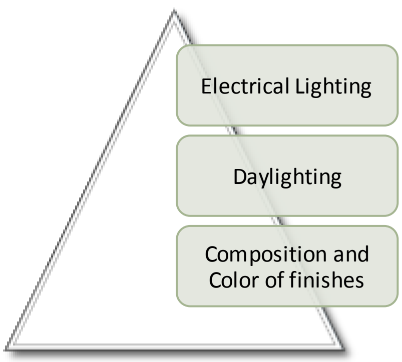


Figure 24 : Energy - efficient Lighting Design

As mentioned in previous section, in order to make best use of high performance glazing with high VLT, lighting fixtures with dimmable ballast were selected for the first and second floor. However, ground floor fixtures were chosen without daylight control. One reason for this was plan of planting trees near the building that would reduce availability of daylight on ground floor.

This would reduce usefulness of dimmable ballast on the ground floor. Internal partitions on all the floors are made of glass, so as to not only provide feeling of roominess, but also to ensure deeper penetration of daylight into the building.

Figure 25 : Naturally day lit computer labs

ARTIFICIAL LIGHTING DESIGN

Use of energy efficient lighting fixtures and good placement of fixtures are two keep elements for reducing lighting load significantly. Approach of high efficiency LED lights, with combination of task lighting and ambient lighting was chosen for this building. Besides energy savings, LEDs offer benefits such as small size, long lamp life, low heat output, and durability. Table below gives lighting power density of different application spaces on different floors of this building:

Table 3: Lighting fixtures installed at ground floor

S.No.	Space Name	Area (Ft2)	Round Panel LED (15W)	SQ. Panel Tube LED (49W)	CFL (9W)	CFL (36W)	LPD (W/ft2)	Area Type
1	EL1 West PerimSpc (G.W1)	8241.2	55	74	0	0	0.5	Office, Lobby
2	EL1 SE PerimSpc (G.SE2)	6510.4	40	51	6	10	0.5	Office, Lobby, classroom, Toilets
3	EL1 Core Spc (G.C3)	327.2	3	2	0	0	0.4	office
4	EL1 Core Spc (G.C4)	493.9	0	4	0	0	0.4	office
5	EL1 West PerimSpc (G.W5)	7998.5	56	57	0	0	0.5	Office, Computer lab, Lobby
6	EL1 NE PerimSpc (G.NE6)	9143.7	44	82	0	0	0.5	Office, Lobby, Toilets
7	EL1 Core Spc (G.C7)	439.3	0	4	0	0	0.4	office
8	EL1 Core Spc (G.C8)	95.4	0	1	0	0	0.5	office
	Overall						0.5	

Table 4: Lighting fixtures installed at first floor

S.No.	Space Name	Area (Ft^2)	6"SQ. Panel LED (12W)	SQ. Panel LED (42W)	CFL (9W)	LPD (W/ft^2)	Area Type
1	EL2 WSW PerimSpc (G.WSW1)	7811.8	113	45	0	0.4	Computer Labs, Lobby, Office
2	EL2 Core Spc (G.C2)	326.1	3	4	0	0.6	office
3	EL2 Core Spc (G.C3)	432.2	1	5	0	0.5	office
4	EL2 West PerimSpc (G.W4)	638.7	12	4	0	0.5	Lobby, Office
5	EL2 Core Spc (G.C5)	408.7	4	4	0	0.5	office, server room
6	EL2 ESE PerimSpc (G.ESE6)	9861.2	155	44	6	0.4	Computer Labs, Lobby, Office
7	EL2 Core Spc (G.C7)	155.0	Not Installed				stairs
8	EL2 NW PerimSpc (G.NW8)half	6292.0	76	38	0	0.4	Computer Labs, Lobby, Office
9	EL2 Core Spc (G.C9)	164.4	Not Installed				office
10	EL2 NE PerimSpc (G.NE10)	2424.6	Closed				Seminar hall
11	EL2 Core Spc (G.C11)	492.6	Not Installed				office
12	EL2 Core Spc (G.C12)	171.4	Not Installed				office
	Overall					0.5	

Table 5: Lighting fixtures installed at second floor

S.No.	Area Name	Area (Ft^2)	6"SQ. Panel LED (12W)	SQ. Panel LED(42W)	CFL (9W)	LPD (W/ft^2)	Area Type
1	EL3 WSW PerimSpc (G.WSW1)	8561	99	50	0	0.4	Computer Labs, Lobby, Office
2	EL3 Core Spc (G.C2)	397.1	0	4	0	0.4	office
3	EL3 Core Spc (G.C3)	431.8	0	4	0	0.4	office
4	EL3 SE PerimSpc (G.SE4)	8600.1	76	42	6	0.3	Computer Labs, Office, Toilets
5	EL3 Core Spc (G.C5)	304.4	4	2	0	0.4	office
6	EL3 East PerimSpc (G.E6)	4995	36	21	0	0.3	Lobby, office
7	EL3 Core Spc (G.C7)	238.7	0	2	0	0.4	office
8	EL3 Core Spc (G.C8)	164.4	0	1	0	0.3	office
9	EL3 Core Spc (G.C9)	126.7	0	1	0	0.3	Toilets
10	EL3 WNW PerimSpc (G.WNW10)	11936.8	140	69	0	0.4	Computer Labs, Office
11	EL3 North PerimSpc (G.N11)	694.7	16	0	0	0.3	Lobby
12	EL3 NE PerimSpc (G.NE12)	2235.3	Not installed				Meeting hall
13	EL3 Core Spc (G.C13)	300.6	4	2	0	0.4	office
14	EL3 Core Spc (G.C14)	346.6	Not installed				stairs
15	EL3 West PerimSpc (G.W15)	620.2	13	0	0	0.3	Lobby, Waiting space
	Overall					0.3	

As the building has fluctuating occupancy levels and as is one of the requirements of ECBC too, occupancy sensors are also used in the building.

Table 6 : Details of LEDs installed

Floor	Selected Fixtures	
Ground Floor		
	15 Watt LED Round Panel	49 Watt LED Square Panel
First /Second		
	12 Watt Square Panel	42 Watt Square Panel

HVAC SYSTEM DESIGN

SELECTION OF UNITS

Air conditioning is responsible for a large part of a building's energy consumption. This project being used for housing high end computer centre and administrative office, is likely to have a significant use of energy for its Air Conditioning. At the same time, the users have a highly variable work timings. The load is usually higher during day due to one floor having administrative offices, and low during nights, and during summer vacation period. This combination of requirement had put challenge for selection of HVAC system type. A system was required that can take advantage of this variable occupancy schedule in its controlling its operational energy consumption. Further, decisions about use of some spaces and their air-conditioning requirements were not finalised at the beginning, requiring modularity and possibility of capacity expansion as features of system selection. Availability of water was also one constraint while selecting HVAC system. Keeping in mind all of the above factors, VRF system was proposed for the building.

Figure 26 : 3 Pane windows (Left) and VRF Air Conditioner Units (Right)

54 nos. outdoor units are installed on roof of building with a total capacity installed is 518 TR. Specification of one such unit is as following:

Table 7 : Specifications of a VRF Outdoor Unit

Power Supply	**380-415V, 50 Hz**
COP	3.75
Capacity	115000 Btu/hr. (9.6 TR)
Input Power	8.93 kW (12 HP)
High pressure side	40 bar (4 MPa)
Low pressure side	33 bar (3.3 MPa)
Refrigerant	R410A
No. of compressors in each unit	2 (Hermetically sealed scroll type)

Pairing of units was done through following considerations:

as per the load to be catered
as per occupancy pattern so as to get more load diversity
as per required length of pipe and duct work

HEAT RECOVERY WHEELS:

The building has two large meeting rooms on the north east corner, each having design occupancy of 120 seats. Due to high occupancy, amount of fresh air delivered to the Air Handling Unit is also high. This offers an opportunity to recover the cooling effect going with outgoing air, Enthalpy wheel of 1200 CFM have been proposed for these two rooms. This not only would result into reduction in operational energy consumption, but through simulations it has been found that it was helpful in reducing the tonnage of air-conditioning units connected to these rooms by about 25%.

DUCT WORK:

Air distribution in conditioned spaces is ducted due to ease of condensate removal and maintenance. Some part of the duct work is of butyl rubber whereas, rock-wool based insulation is also used.

RENEWABLE ENERGY INTEGRATION: SPV PLANT

The top tier of the energy efficiency pyramid is renewable energy integration. Jaipur has a very high solar energy potential. Since this building has no tall structure in its close vicinity, availability of sunshine was utilised through harnessed it using solar PV plant. Following were major factors for taking this decision: Reduction of withdrawal of power from grid and to avoid use of diesel generator set during power cuts. For this reason, the PV system was designed to have a two hour back up for lighting and computers used in this building.

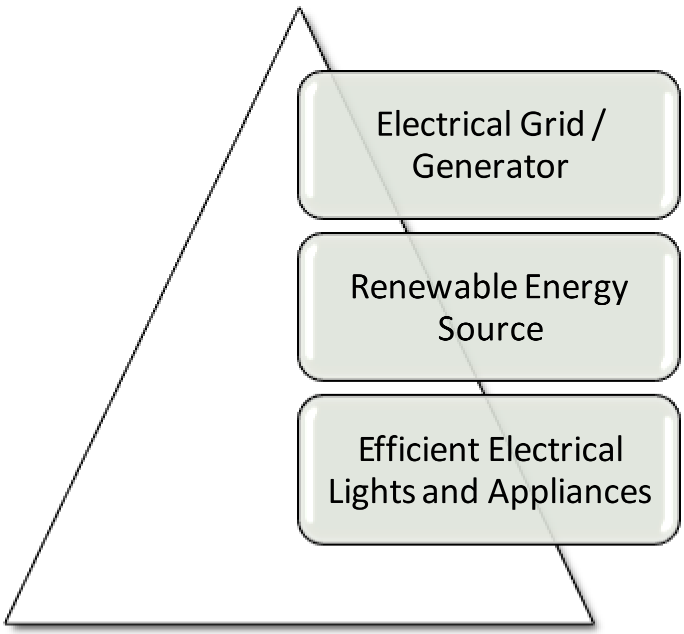


Figure 27 : Efficient Energy Usage in Building Design

As per the availability of roof area and requirement of roof for hosting other services, such as outdoor units of air conditioners, decision for installing 157.5 kW_p SPV system was taken. It was further decide to have three sets of 52.5kW_p each. The idea was to have one set for each of the floors.

As there would be surplus power expected from the proposed rooftop PV system during weekend and holidays, the system was designed to have two way flow of power and metering. MNIT Jaipur is having metering of it energy consumption only at the HT connection point, this fact allowed to have a system that can export surplus power to local LT grid, thereby reducing energy consumption from HT point.

Figure 28: Roof top SPV plant at Prabha Bhawan (Previously known as Design Centre) building

SELECTION OF PV MODULE

Mono crystalline silicon cell based modules were selected to be used in these systems. Care was taken for ensuring high efficiency and low temperature coefficients of cell. Typical module capacity of 250W_p was chosen to ensure that the modules are neither too small, nor too large to get adversely affected by wind forces. Table below presents specifications of the PV module used for plant.

Table 8: 250 WpSPV module details

Type	Mono Crystalline Silicon
Height	5.44 Ft
Width	3.27 Ft
Open Circuit voltage (V_{oc})	37 V
V_{oc} Temperature coefficient	-0.05 V/°C
Short circuit current (I_{sc})	8.8 A
I_{sc} Temperature coefficient	0.00344 (1/°C)
Maximum power voltage	30.28 V
Maximum power current	8.3 A

DETAILS OF SPV PLANT

630 modules of mono crystalline silicon have been connected in series and parallel combination at the terrace of Prabha Bhawan (Previously known as Design Centre) building. For every 52.5kW$_p$ capacity, there are fifteen modules connected in series to form a string of the plant. Fourteen such strings are connected in parallel, further this series parallel combination is connected to a Junction Box and from junction box, wires are connect to inverter for conversion of DC to AC. Total installed module capacity turns out to be higher than 150kWp, which was done to offset losses and de-rating of modules.

At first floor of the building, in the south west corner room, three Power Conditioning Units (PCU), having inverters and other controllers, are installed with a computerised monitoring system.

Three plants of 52.5 kW$_p$ are grouped together to form 157.5 kW$_p$ of whole SPV plant capacity at building.

Installed Capacity = 157.5 kW$_p$
Number of PV module = 630
Number of Inverters = 3
Inverter Capacity = 50kVA/inverter; η=93% at full load
Number of modules in a string = 15 } X 3
Number of strings in parallel = 14

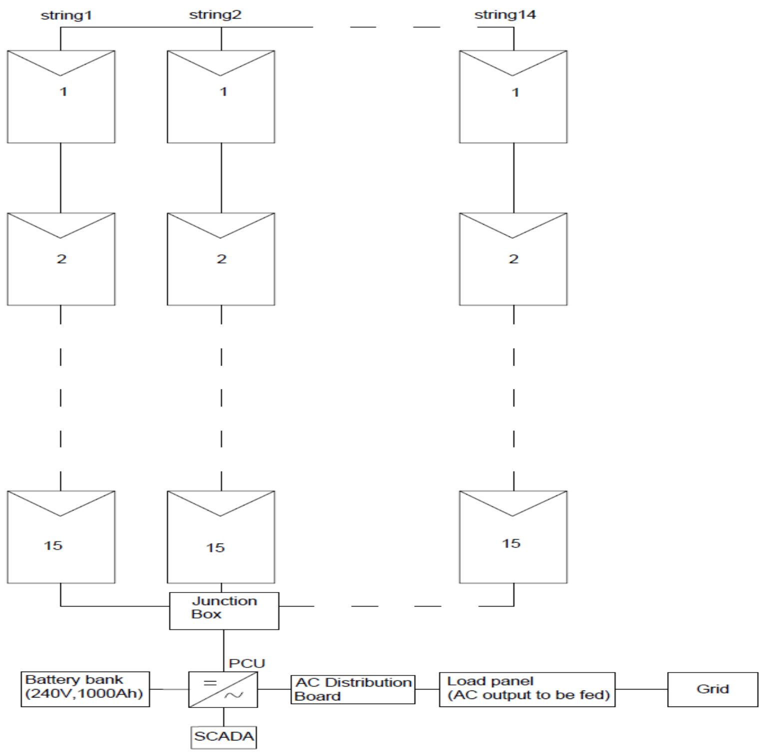


Figure 29 : Schematic block diagram of the SPV plant of 52.5 kW$_p$Plant

INVERTER DETAILS

Inverters are used for DC to AC conversion. Good inverter should have minimum value of Total Harmonic distortion (THD), so that output wave shape shall be closer to sine wave.This SPV plant is having three central inverters installed at first floor of building. Use of string inverters was an alternate available, but considering the length of cabling, efficiency of inverter, availability and cost, central inverter approach was chosen. It was decided to have inverters of 93% full load efficiency and high part load efficiencies.

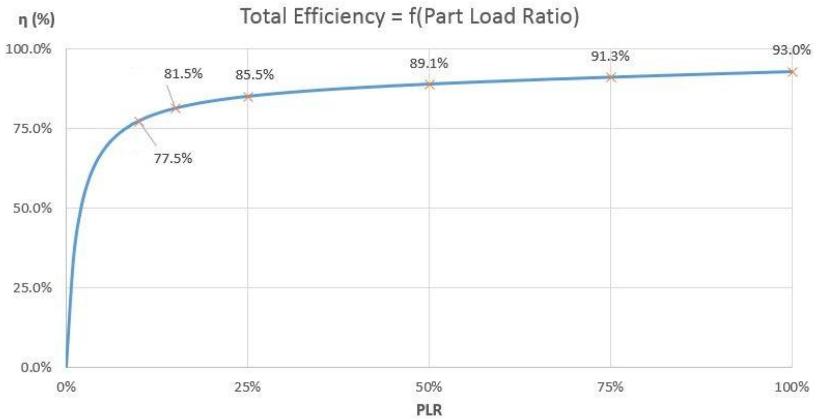


Figure 30 : Operating Efficiency of the Inverter at different loads

ANNUAL ENERGY GENERATION:

On the basis of eQUEST results, the 157.5kW$_p$ SPV power plant is estimated to generate307 MWh electricity, operating at an average annual capacity utilization factor of 22%. Monthly generation from the plant is shown below:

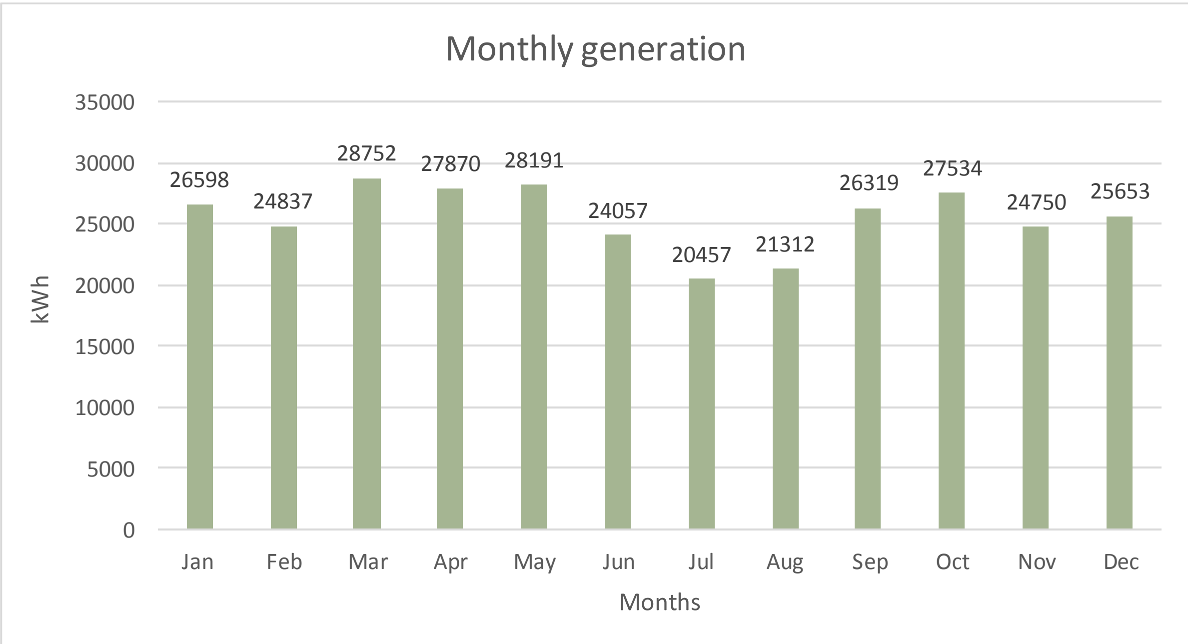


Figure 31: Monthly generation from SPV plant

PERFORMANCE ASSESSMENT AND COMPLIANCE CHECKING

Whole building performance approach is an alternative to the prescriptive approach of Code Compliance and it applies to all building types covered by the ECBC Code. A building complies with the whole building performance approach whenthe estimated annual energy use of the proposed design is not more than the standards design case, even though it may not comply with some specifications of the prescriptive requirements; while meeting all the mandatory requirements of ECBC.Hourly energy simulation tool eQUEST has been used to check code compliance of this building, through the weather file of Jaipur city as available in ISHRAE Weather Data 2014.

CREATION OF GEOMETRIC MODEL OF BUILDING:

Using the building plans and elevations, geometric model was first created. Same geometric model was used in standard case and proposed case.Views of the model as obtained from eQUEST are given below.

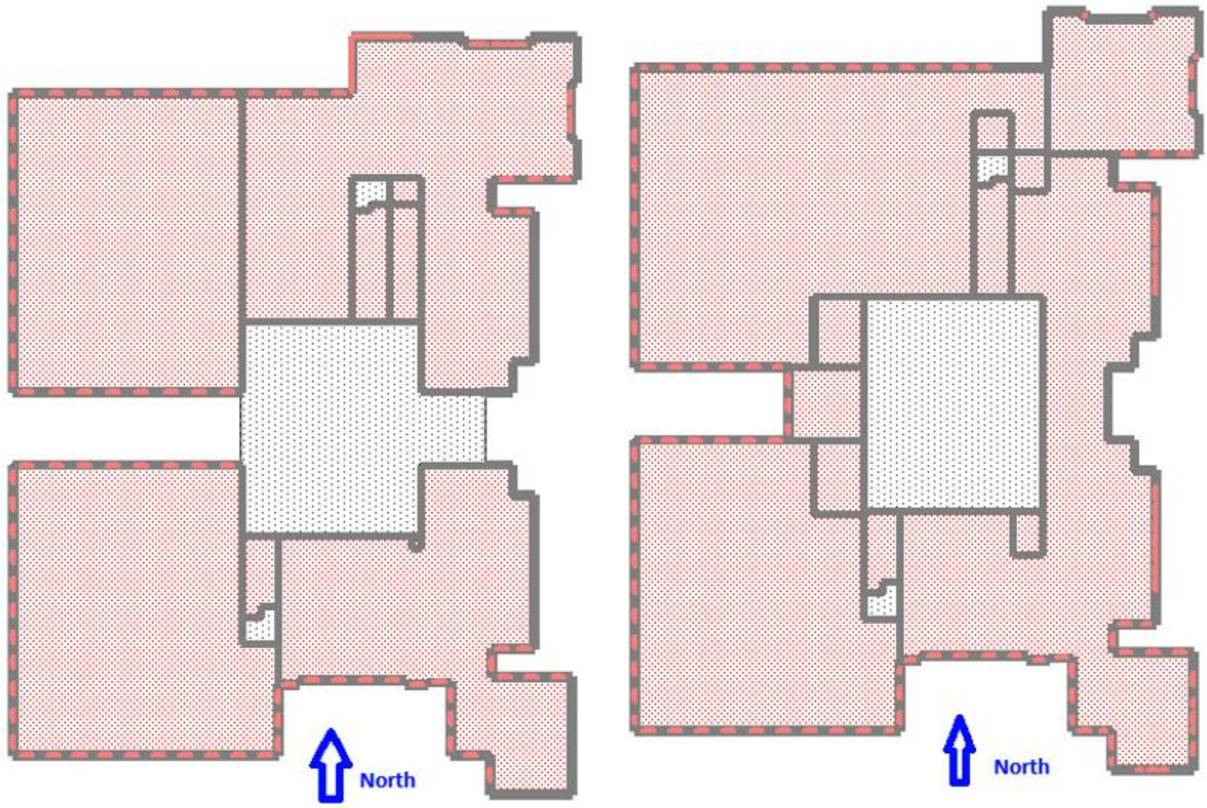


Figure 32 : Ground Floor and First Floor plan (eQUEST)

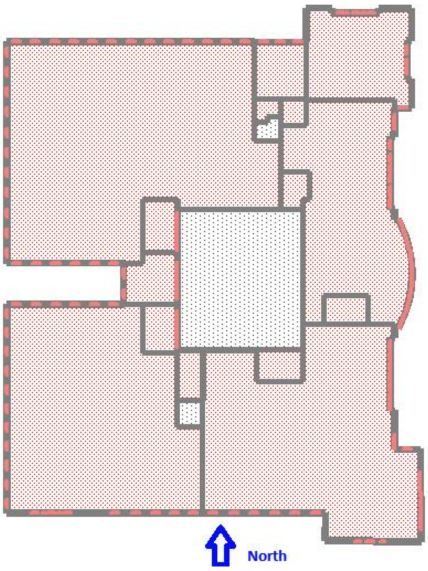


Figure 33 : Second Floor plan (eQUEST)

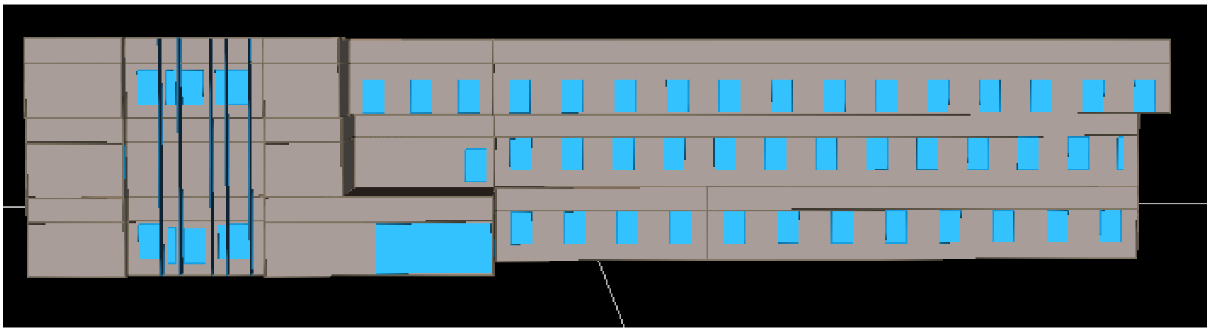


Figure 34 : North Side Elevation

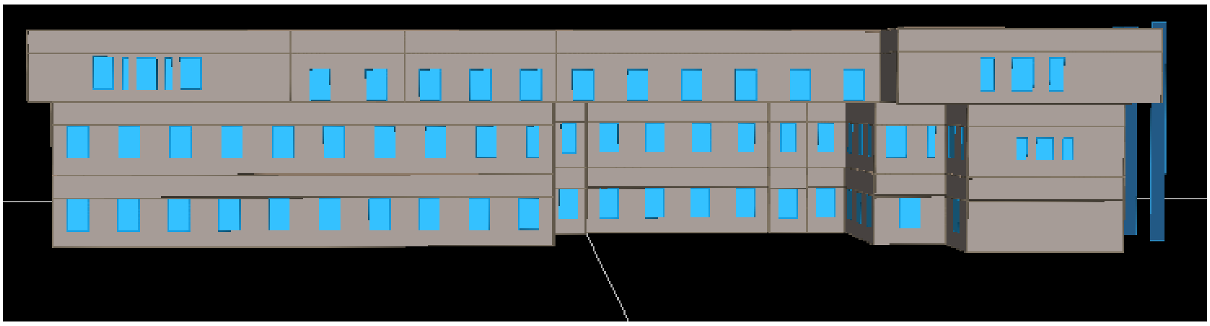


Figure 35 : South side elevation

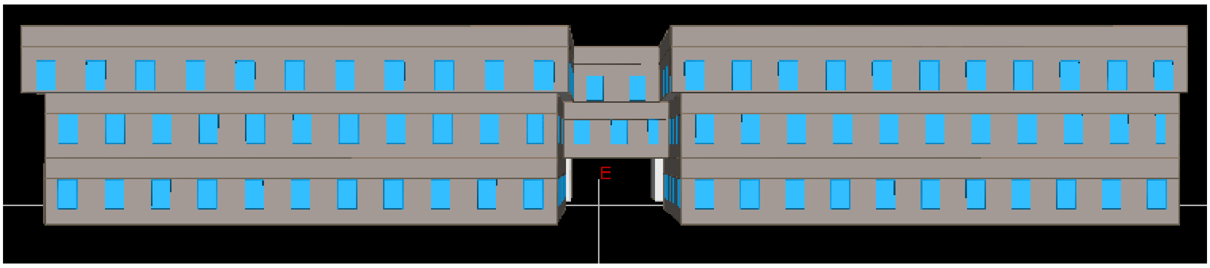


Figure 36 : West side elevation

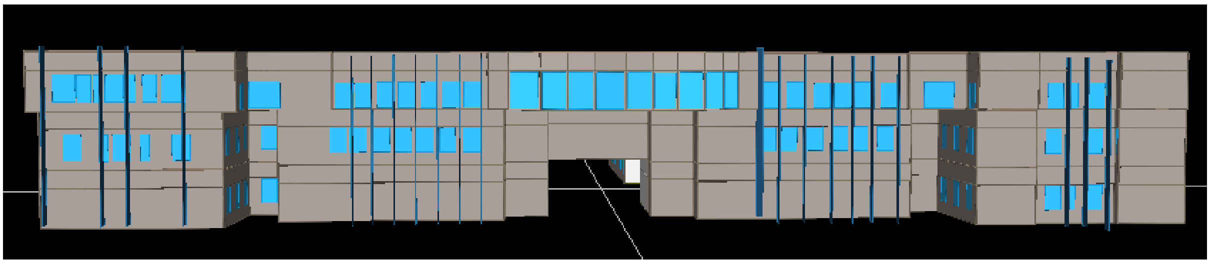


Figure 37 : East side elevation

MODELLING STANDARD CASE

A standard case was developed using ECBC and its user guide. ASHRAE 90.1-2004 standard was referred for clarifications as mentioned in ECBC User Guide.

Table 9 : Specifications for developing model of standard case as per ECBC

Criteria for Roof and Wall in Composite Climate (Table 4.1 & 4.2 of ECBC)	
Roof [U-value (W/m^2°C)]	0.409
Wall [U-value (W/m^2°C)]	0.44
Criteria for Glazing in Composite table (Table 4.3 & 4.5 of ECBC)	
Solar heat gain coefficient	0.25
U-value (W/m^2°C)	3.3
Visual light transmittance	0.27
Lighting power density (Table 7.1 of ECBC)	
Building type is office cum labs for training	10.8 W/m^{2}LPD
Occupancy and Equipment power density (EPD) (Table 10.1)	
Occupancy	In standard case occupancy is taken same as actual case, occupancy observed in actual case is 57, 58, and 60 ft^2/person for ground, first, and second floor.
EPD	In standard case EPD is taken same as actual case (ECBC user guide Table 10.1), EPD observed in actual case is 1.13, 2.2, and 2.2W/ft^2 for ground, first, and second floor.
HVAC system (Table 10.2 of ECBC)	
Non-residential building which has conditioned area 7,500 to 15,000 m2	Central cooling plant with constant volume AHU for each zone. Current building is having 9959 m^2 conditioned area, therefore this cooling plant is applicable.
COP	3.04 (ECBC Table 5.1), air cooled screw chiller, since proposed case has air cooled system

DETAILS OF HVAC SYSTEM IN STANDARD CASE

Type: RHFS (Reheat fan system)

Fan control: Constant volume air handler for each zone
Cooling type: Chilled water
Chiller type: Electric screw, air cooled
From ASHRAE 90.1-2004: One number of chillers required corresponding to 9959 m^2 of conditioned area of building.

Table 10 : Number of chillers required corresponding to conditioned area

Building – conditioned floor area	Number and type of chiller (s)
$\leq$ 11,148 m^2	Screw chiller
>11,148 m^2, <22,296 m^2	2 screw chillers sized equally
$\geq$ 22,296 m^2	2 centrifugal chillers minimum with chillers added so that no chiller is larger than 2813 Kw , all sized equally

As per ECBC User guide, in standard case model, Chilled water design supply temperature was kept as 6.7°C. Chilled water return temperature was kept at 13°C.

CALCULATION OF FAN POWER FOR STANDARD CASE:

It is calculated on the basis of ECBC user guide table 10.2

Table 11: Standard Fan Brake Horse power (ECBC User Guide Table 10.2)

Supply Air Volume	Baseline Fan Motor Brake Horsepower	
	Constant Volume Systems 1 – 4	Variable Volume Systems 5 – 8
< 9400 L/s	17.25 + (cfm - 20000) × 0.0008625	24 + (cfm - 20000) × 0.0012
9400 L/s	17.25 + (cfm - 20000) × 0.000825	24 + (cfm - 20000) × 0.001125

P_{fan}: $746 / (1 - e[-0.2437839 \times \ln(bhp) - 1.685541]) \times bhp$

Where P_{fan}: electric power to fan motor (watts)

bhp: brake horsepower of Standard fan motor from the table below, where cfm represents design supply flow rate.

Supply air: 217225 CFM, Brake horse power calculated from above table: 180 bhp
Fan power: 141.6 kW, therefore fan power in kW/CFM would be 0.000652.

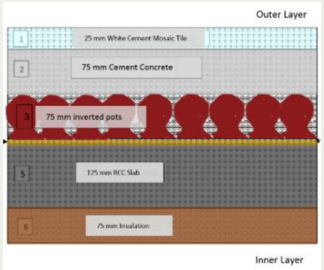
MODELLINGPROPOSED CASE

Specifications for modelling the proposed case building were developed by using actual architectural drawings, constructions details and product catalogues.

Table 12 : Envelope details for the Design Case

Envelope (Roof)

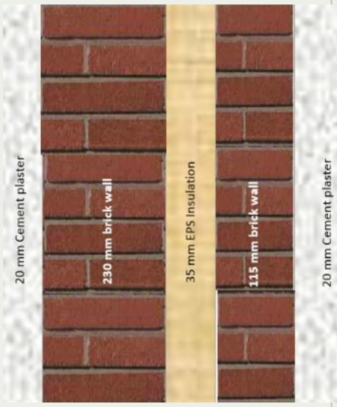
U-Value (0.35W/m²K)



Inner surface	
Convective heat transfer coefficient (W/m2-K)	4.460
Radiative heat transfer coefficient (W/m2-K)	5.540
Surface resistance (m2-K/W)	0.100
Outer surface	
Convective heat transfer coefficient (W/m2-K)	19.870
Radiative heat transfer coefficient (W/m2-K)	5.130
Surface resistance (m2-K/W)	0.040
No Bridging	
U-Value surface to surface (W/m2-K)	0.371
R-Value (m2-K/W)	2.835
U-Value (W/m2-K)	**0.353**
With Bridging (BS EN ISO 6946)	
Thickness (m)	0.405
Km - Internal heat capacity (KJ/m2-K)	0.0000
Upper resistance limit (m2-K/W)	2.835
Lower resistance limit (m2-K/W)	2.835
U-Value surface to surface (W/m2-K)	0.371
R-Value (m2-K/W)	2.835
U-Value (W/m2-K)	**0.353**

Envelope (Wall)

U-Value (0.72 W/m²K)



Inner surface	
Convective heat transfer coefficient (W/m2-K)	2.152
Radiative heat transfer coefficient (W/m2-K)	5.540
Surface resistance (m2-K/W)	0.130
Outer surface	
Convective heat transfer coefficient (W/m2-K)	19.870
Radiative heat transfer coefficient (W/m2-K)	5.130
Surface resistance (m2-K/W)	0.040
No Bridging	
U-Value surface to surface (W/m2-K)	0.815
R-Value (m2-K/W)	1.397
U-Value (W/m2-K)	**0.716**
With Bridging (BS EN ISO 6946)	
Thickness (m)	0.145
Km - Internal heat capacity (KJ/m2-K)	66.5392
Upper resistance limit (m2-K/W)	1.397
Lower resistance limit (m2-K/W)	1.397
U-Value surface to surface (W/m2-K)	0.815
R-Value (m2-K/W)	1.397
U-Value (W/m2-K)	**0.716**

Envelope (Glazing)

Double glazed unit: 6mm coated glass-12mm air gap-6mm clear glass

U – Value 1.9W/m²K)	Solar heat gain Coefficient	0.28
	Visual light transmittance	0.39

HVAC System:

System type: VRF

COP: 3.75

Condenser: Air cooled

HVAC Schedules in both standard and actual case are same as per ECBC user guide Table 10.1

The summary of all the factors considered for the actual and the standard case is as following:

Table 13 : Summary of considered factors

Criteria	**Standard Case**	**Design Case**
Building Envelope		
Roof [U-value (W/m² ℃)]	0.409	0.35
Wall [U-value (W/m² ℃)]	0.44	0.72
Glazing (SHGC)	0.25	0.28
Glazing [U-value (W/m² ℃)]	3.3	1.9
Glazing (VLT)	0.27	0.39
Air Conditioning		
HVAC	RHFS (COP = 3.05)	VRF (COP = 3.75)
Schedules		
Occupancy (ft²/person)	58	58
Lighting (W/ft²)	1	0.43
EPD (W/ft²)	2.2	2.2

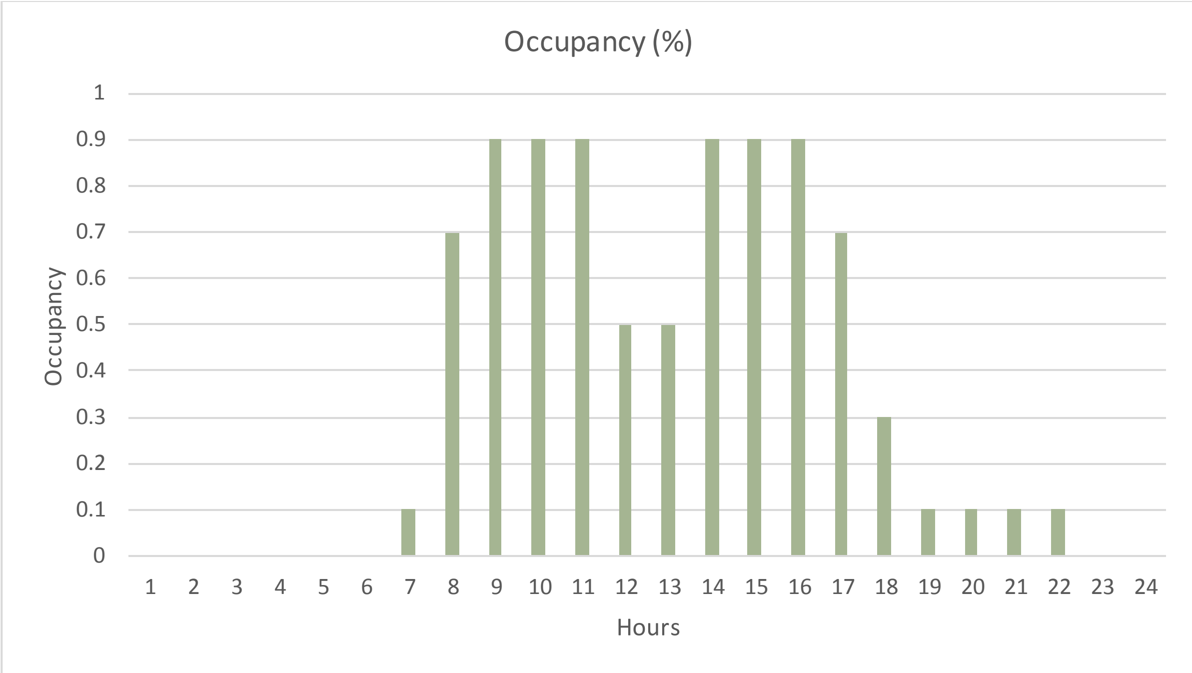


Figure 38 : Occupancy Schedule

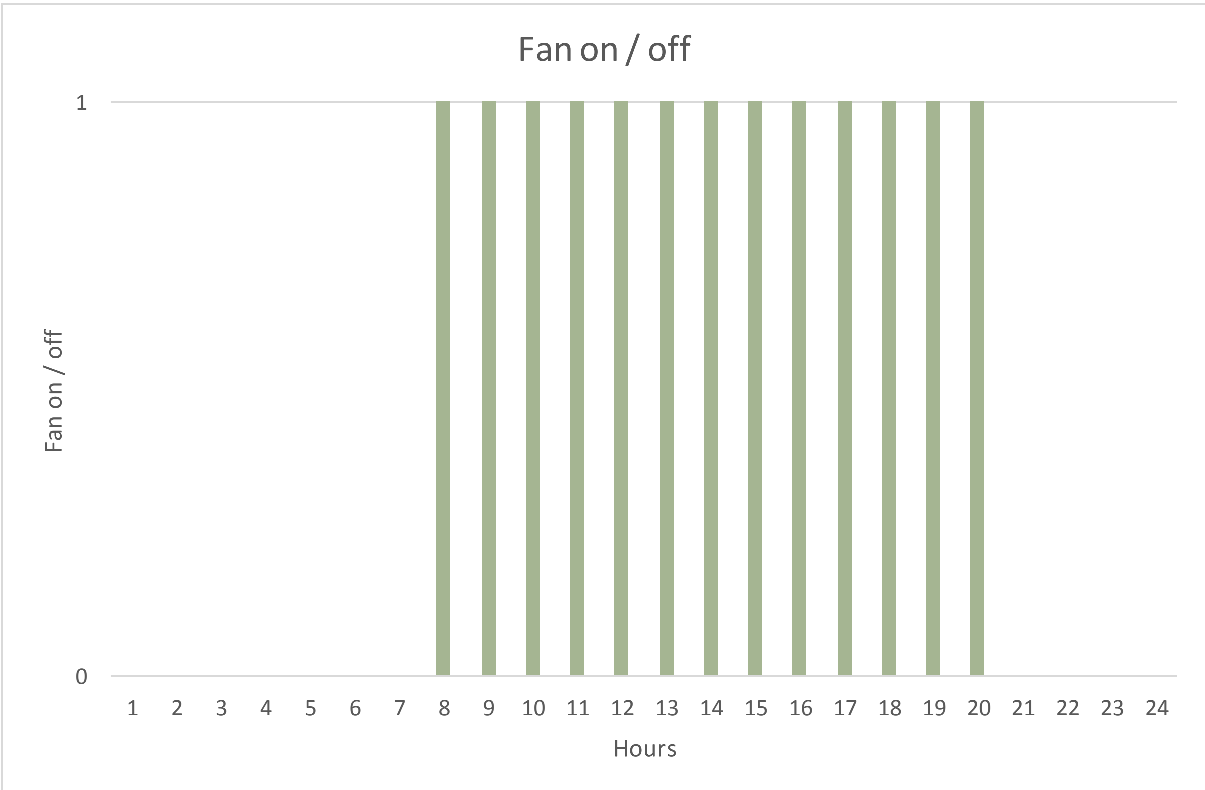


Figure 39: Fan Schedule

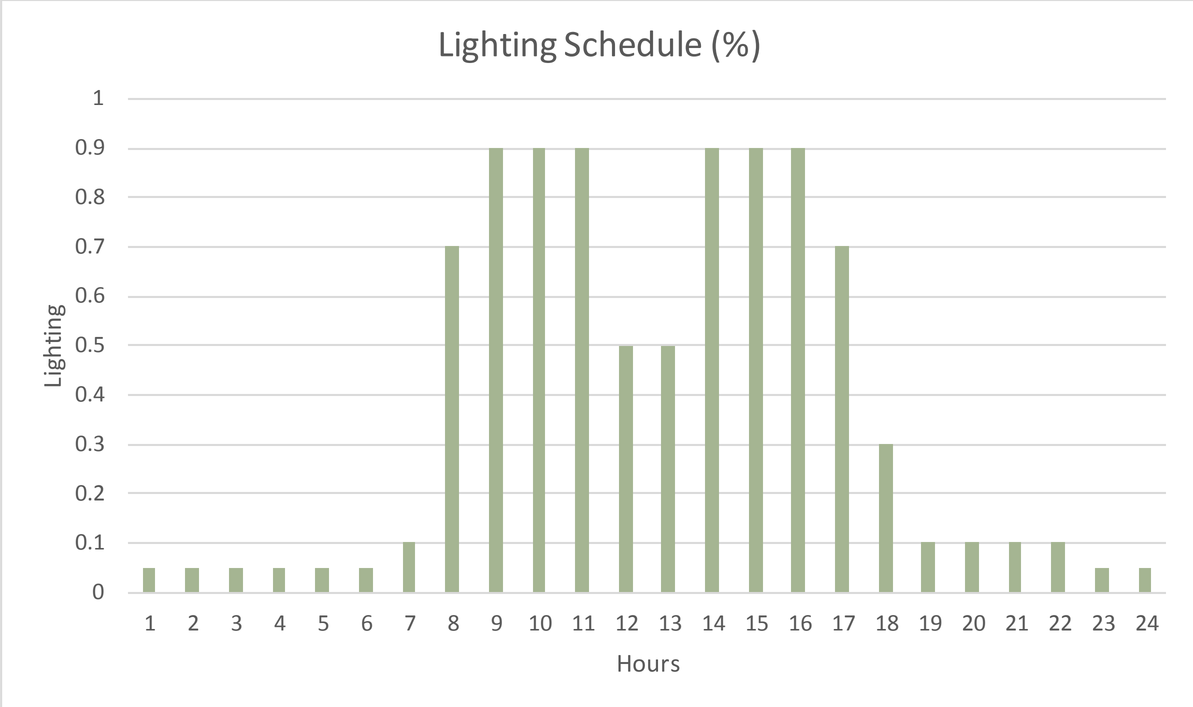


Figure 40 : Lighting Schedule

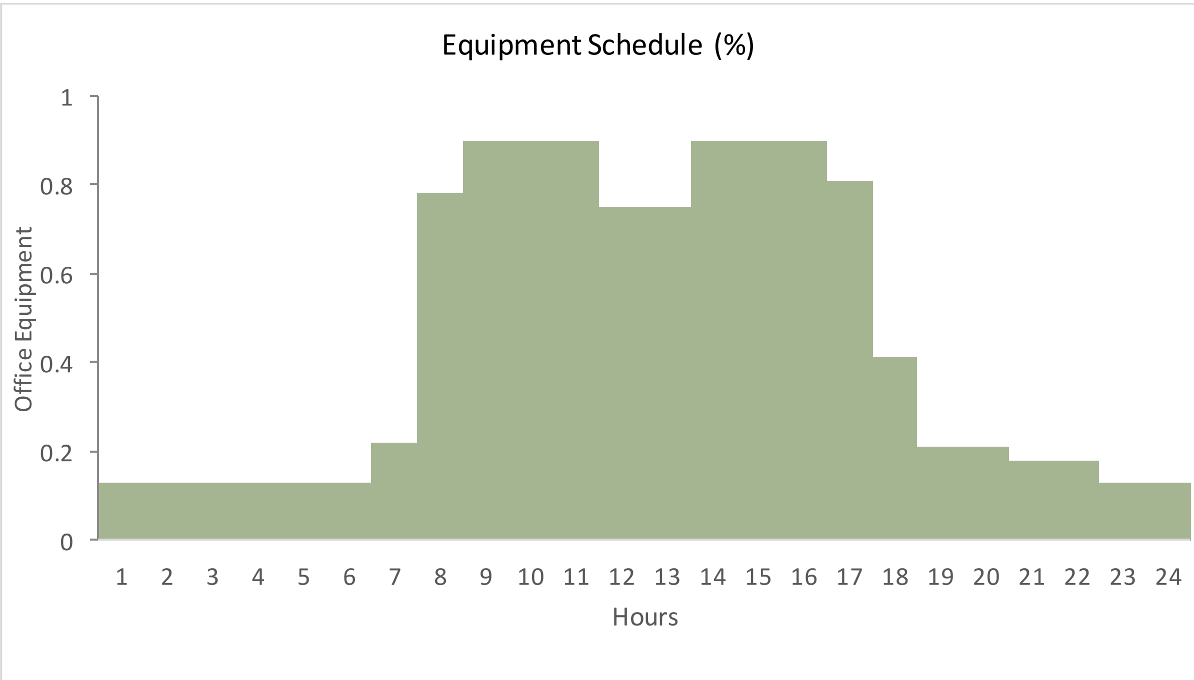


Figure 41 : Equipment Schedule

ENERGY CONSUMPTION OF STANDARD CASE

Monthly energy consumption and end use wise break up of energy consumption in the standard case are shown in Figure 43.

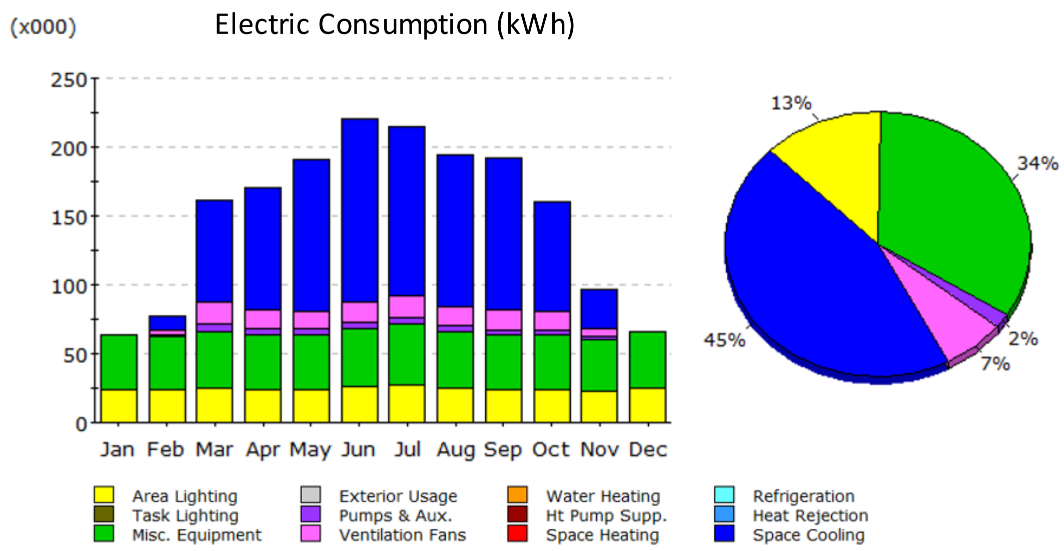


Figure 42 : Monthly gross and end use wise energy consumption (Standard Case)

ENERGY CONSUMPTION OF PROPOSED CASE

Monthly energy consumption and end use wise break up of energy consumption in the design caseare shown in Figure 44.

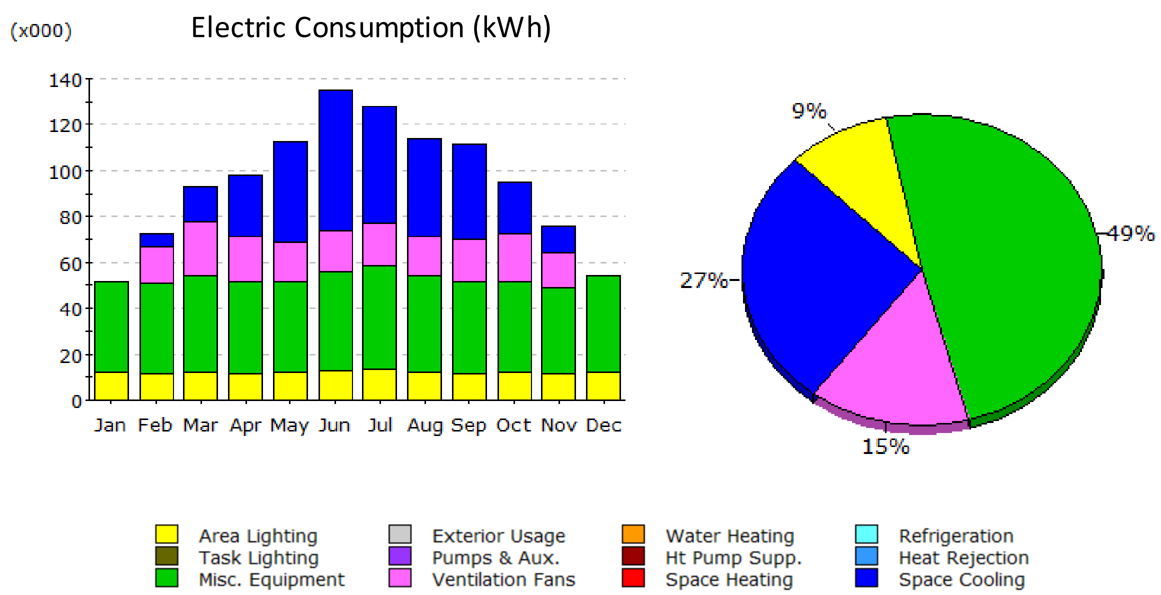


Figure 43 : Monthly gross and end use wise energy consumption (Design Case)

Annual Comparison of the standard case and design case are presented in table below. It shows 30% energy savings over standard case which establishes that this building is not just ECBC compliant as per Whole Building Performance Method of ECBC, it is performing about 30% better than the code requirements.

Table 14: Annual energy savings over ECBC Standard case

	Standard case	Proposed case	Savings (%)
Energy consumption (kWh)	2057.7 x 1000 = 2057700	1449.6 x 1000= 1449600	30
EPI (kWh/m^2/yr)	182	128	30
Annual peak demand by end use (kW)	1020	801	22

Further, it has been found that the peak electricity demand is 22% less than that of the standard case, which is though not any requirement of ECBC but can be an additional benefit of selecting energy conservation measures.

GENERATION FROM SOLAR PHOTOVOLTAIC SYSTEM

In the analysis above, electricity generation from the 157.5kW$_p$ Solar PV system has not been considered. Simulation output for PV plant on roof of this building is shown in Figure-32.
It shows that on annual basis, the plant supplies 3, 07,000 kWh electricity to the building. This is 21.2% of the annual electricity consumption. The system is already in place and if that electricity generation is counted towards energy savings, the building is likely to save about 50% electricity over ECBC Standard case.

PAYBACK ANALYSIS

While taking decisions, payback analysis was carried out using approximate model of the building. Energy conservation measures were considered initially in isolation, but later in combination of each other keeping the following in mind:

Effectiveness and payback of some ECMs improved in presence of other ECMs. DGU is one typical example, which gives better payback if the building is using insulation on roof and wall, and if SHGC of glass is low. Else its payback appears to be very high. Similar would be the case of roof and wall insulation and several other combinations.

While calculating payback period, it is important to consider reduction in capacity of air-conditioning system, and reduction in the avoided cost from the additional investment for adopting ECMs. In some cases, as shown in example below, significant reduction in capacity can be observed and if overlooked, may create wrong impression about usefulness of ECMs.

Since the number of combinations analysed in this case were very large, the table below only presents, a typical example of decision making process that was adopted. The costs used in this table are also indicative and were used to carry out initial analysis. It is slightly difficult to establish payback period of incremental investment of whole building in this case, due to several reasons:

This, being a government project, was carried out as per approved norms and procedures. In some cases, due to new situations arising, such as some materials not being there in the approved schedule of rates at that point of time, the procurement period was increased.

Price negotiations possibilities that are many a time possible with private sector nearly did not exist.

Market for energy saving products was developing at that stage, in case of several products, such as LED lights, PV modules, costs might have significantly come down between the time of procurement for this building and now.

Table 15 : Sample payback analysis of Energy Conservation Measures

	Normal construction	1" roof + 1" wall	1.5" roof + 1.5" wall	2" roof + 2" wall
Roof insulation (inches)		1.00	1.50	2.00
Wall insulation (inches)		1.00	1.50	2.00
Energy consumption kWh/yr	1562100	1444400	1442200	1429800
Reduction in TR	0.00	77	80	82
Saving in Rs/yr @8/- per kWh		941600	959200	1058400
Cost of roof insulation (Rs.)		2400000	3600000	4800000
Cost of wall insulation (Rs.)		4500000	6750000	9000000
Total cost of insulation (Rs.)		6900000	10350000	13800000
Payback (yrs)		**7.3**	**10.8**	**13.0**
Avoided cost due to reduced TR		3850000	4000000	4100000
Revised extra investment		3050000	6350000	9700000
Revised payback		**3.2**	**6.6**	**9.2**

CONCLUSION

This project has paved way for ECBC implementation in existing buildings as well as the proposed ones. ECBC implementation has been surrounded with a lot of questions since its inception. Every new initiative has to face a lot of uncertainty. Such projects help in clearing out the fog and make the way clear. The results in this particular show significant decrease in the energy usage as and delivery of a better performance. On one hand, the building performance was enhanced whereas on the other hand, few issues came forward, which need to be dealt with to strengthen the implementation process. They will also make the process easier.

Procurements in public buildings like those on MNIT's campus can be complex. MNIT found that all the materials and equipment needed for ECBC compliance were not available on the "Schedule of Rates" that the Central Public Works Department maintains. This slowed down the procurement of LED lighting in the Prabha Bhawan (Previously known as Design Centre) . It affected other procurements for ECBC materials, which in some cases lowered the efficiency of the building. MNIT compensated for this by adding 150 kW of solar PV. The Bureau of Energy Efficiency has since worked with the Central Public Works Department to update the Schedule of Rates, however, public buildings must still show lowest first cost, which is a challenge for many efficiency measures which typically have low life cycle costs, but slightly higher first costs.

MNIT conducted significant analysis to build the business case for purchasing materials and equipment that helped with ECBC compliance. This information will be helpful to other public facilities.

Manufacturers may overstate energy performance of the materials and equipment. MNIT noticed this when they conducted their own simulation of the windows they planned to install. A robust system to test, rate and label products will make ECBC implementation easier.

MNIT was able to use eQUEST, a building energy simulation program, to assess whether the planned design met ECBC requirements. It would be very helpful to have robust, easy-to-use compliance software. This requires improving the functionality of ECOnirman.

All central government public buildings must now meet ECBC requirements because they must have a green building certification. Public buildings do not need to receive construction or occupancy permits from the local government, but rather, they receive this approval from the central or state public works departments. Strengthening the capacity of these public works departments to implement ECBC in all their buildings will help build momentum to mainstream ECBC implementation.

Due to ease of interpretation of requirements, CPWD and other Govt. organizations prefer prescriptive method of compliance. Whereas, in case of MNIT, whole building method has been preferred. Due to this, some requirements were to be made more stringent than ECBC prescriptive values to compensate for other components. This made the procurement process significantly lengthier. One such case has been lighting, in which the LPD chosen is much lower than ECBC requirements, thus raising the level of specifications of lighting fixtures and controllers.

Due to the lighting control system not being a usually procured system in buildings, project staff needs technical support for preparation of tender document and screening of bids.

Help of live demonstration of such system is also useful approach for convincing those who are not in this space but are part of decision making process.

TESTIMONIALS

Authorities' perspective:

"The project is an example of excellent team work between the facilitators, administrators, the vendors and above all the executors. Projects like this require excellent management which has been a good learning experience for the Institute. "

I.K. Bhat, Director, MNIT

"The building is a landmark in the institute and it has been a learning process for the facilitators and has paved the path for energy efficient buildings in the campus."

RohitGoyal, Dean, Planning and Development, MNIT Jaipur

"Non- Renewable energy sources are limited and projects like this help in putting the institutions on the right path. Such projects are cost efficient in the long run and put the institute apart. It's a good feeling to know that our systems are part of such a prestigious building"

A.K. Jain, MD, REIL

"The project is an example of a well-structured approach towards achieving energy efficiency. The benchmarks like ECBC Compliance help in quantifying the goals. In current times, the decrease in energy usage is a very important aspect of building industry. An institute like MNIT has set an example by doing this project."

Sunit Mathur, GM, RRECL

USERS' PERSPECTIVE:

"The building has good working environment, we have become more conscious about energy efficiency in our lives after starting to work inside this the building."

Awadhesh Bhardwaj, Dean (Research & Consultancy), MNITJaipur

"Light is an important factor for comfortable working in a computer lab. The long hours of concentrating on a computer screen are less stressing due to the quality of light inside the labs"

Sanjay Rajpal, Central Computer Centre, MNIT Jaipur

PROJECT TEAM

MNIT:

Director, Dean (Planning and Development), Associate Dean (Planning and Development), Head, Centre for Energy and Environment, In-charge Computer Centre, Registrar, Engineers of Estate Section.

RAVIL:

Executive Engineer and team

Most of the decisions were taken through open discussions and deliberations held in meeting inviting major stakeholders. Major concerns in the meeting have been availability of material, aesthetics, skill required, maintainability, energy consumption and cost. Most decisions were taken on the basis of life cycle analysis and long term implications.

LIST OF ECMS:

Double glazed window with low U-value

Low SHGC Glass

High VLT glass

LED Lights

Daylight integration

Heat recovery wheel

VRF based air conditioning systems

Insulation in wall

Insulation in roof

Thermal mass

Shading fins and self shading design

Courtyard

INFORMATION DISSEMINATION:

Visits of BEE Certified ECBC Master Trainers

Officials of Rajasthan Renewable Energy Corporation

ISHRAE members: Holding workshop in the building

Visit of Secretary, Ministry of Human Resource Development, Govt. of India

Visit of Vice Chancellors of Universities participating in West Zone VC's meet

German Ambassador along with Director DAAD, Director Goethe Institute, and representatives from German Universities

Indian and US Partners of PACE-R Project 'CBERD' on Energy Efficiency in Buildings

Engineers of Central Public Works Department, Government of India

Engineers of State Public Works Department, Government of Rajasthan

Architects and HVAC consultants and engineers practicing in Jaipur

Students from Department of Architecture and Planning and Centre for Eneregy and Environment, MNIT Jaipur