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Energy efficiency of office building with respect to passive techniques in composite climate

[1] **Mohd Zeeshan Siddiqui,** [2] **Asst.Prof. Jitendra Diwakar,**
[1]Student, [2]Faculty in FOAP,AKTU
[1]Faculty of architecture and planning,
[1]Masters in architecture (General) Lucknow, India

Abstract: Building sector is the one of the emerging industries and also one of the industries which has the highest consumption of energy. Commercial and office building are the biggest user of the energy. As analyzing the recent scenario, the crises of fossil fuel and power shortage also had the impact on this sector. The increase in energy consumption and high energy prices the people are shifting to the renewable sources and incorporating the energy efficiency design techniques and strategies to minimize the usage. In this research paper passive design techniques will be discussed.
The paper involves the generic building shapes which are (square, rectangle, rectangle + courtyard, square +courtyard) these building was placed in the software design builder for simulation with different orientation and different window to wall ratio (WWR) in order to derive which orientation with the better WWR is suitable for composite climate.

***IndexTerms* – Window to wall ratio, Energy performance index, Passive design, Fuel breakdown.**

I. Introduction

In recent years, sustainability has become increasingly important in the construction business. There has been a drive to create buildings in a more efficient and sustainable manner by lowering energy consumption and operating and maintenance costs. A green building is the result of a design concept that emphasizes sustainability. Focuses on improving resource efficiency (energy, water, and materials) while minimizing the building's influence on human health and the environment improved design, construction, operation, maintenance, and removal throughout the lifecycle (Khosla & Singh, 2014)

In order to achieve its energy needs, India faces formidable obstacles. In comparison to 2003-04, India's primary energy supply will need to rise by 3 to 4 times, and its electrical generation capacity/supply would need to grow by 5 to 6 times if it maintains its current growth rate of 8% per year. By 2031, it is expected. The country is now predicted to have a 9.9% electricity shortage and a 16.6% peak demand shortage. Domestic and commercial sectors account for over one-third of total electricity consumption, and they are expected to consume nearly 37% in 2020-21 (Kapoor, 2010).

Every stage of the life cycle, buildings consume energy at different levels and for diverse purposes. Energy consumed for material manufacture, transportation, and construction in an operating phase of a building with at least a 50-year lifespan is "at least five times" what is required in the amount of energy utilized and operational phases. At this point, a considerable portion of the energy (35–60%) is required for heating, air conditioning, ventilation, and artificial lighting. Most buildings, if you live a long period deemed more than 50 years, have energy-efficient ways that have the ability to significantly reduce energy consumption.

II. Energy Efficiency and its Parameters

2.1. The energy efficiency of a structure is defined as how closely its energy consumption per square meter of floor area compares to recognized energy consumption benchmarks for that type of structure under specific climatic conditions. Building energy consumption benchmarks are typical building kinds' representative values that can be used to compare a structure's actual performance. (africa)The typical benchmark indicates the highest quartile performance of all the buildings in a certain category, and also represents the median level of performance of all the buildings in that category. By comparing the standard of energy efficiency to basic benchmarks such as annual energy use per sq. meter of floor space or treated floor area (kWh/m2/annum), the standard of energy efficiency can be examined and priority areas for action highlighted. (africa)
It is stated by term energy performance index (EPI) (SN Srinivas, 2015)

EPI=Total energy consumed in a year (kWh) / Total floor area of the building (m_2)

2.2. Parameters of Passive Design

Orientation

When the weather is hot, buildings should be designed so that shaded indoor and outdoor living areas are available, and when the weather is cold, sunny indoor and outdoor living areas with wind protection are available. The installation of passive technologies within the design is governed by the orientation of the building blocks. It also determines the size and location of windows, which affects both illumination and air conditioning within a structure. When combined with passive design technology, proper orientation can result in significant reductions in lighting and space conditioning load. (Hasim Altan, 2016)

Building shape

If planned according to climatological criteria, the massing of the building components can help reach thermal and visual comfort levels. Wind is channeled or obstructed by building blocks, which also act as shading mechanisms for the environment. Wind flow and velocity can be influenced by the design and geometry of the building blocks. In the summer, massing of blocks can help manage the wind and achieve ventilation, but in the winter, it can restrict wind passage. (Hasim Altan, 2016)

Envelope material

The material chosen is determined by the surrounding climate. However, the material features that regulate their use can be divided into three categories: color, insulating property, and assembly type. The amount of heat and light absorbed and reflected will vary depending on the color of the finish. The lighter the color, the greater the reflectance, while the deeper the color, the larger the absorption. In addition, material selection is influenced by the insulating property. To limit heat, transfer between the internal and external spaces, good insulation is essential. (Hasim Altan, 2016)

Window to wall ratio(WWR)

The window-to-wall ratio (WWR) is the percentage of exterior wall surface area that is glazed (made up of windows), and it has an impact on a variety of architectural characteristics: The physical/visual connection to the outdoors is established by window size, which also dictates the environmental implications associated with material use. (Luke Troup a, 2019)

$$\text{WWR}\ (\%) = \frac{\sum \text{Glazing area}\ (\text{m}^2)}{\sum \text{Gross exterior wall area}\ (\text{m}^2)}$$

Landscape

Landscaping is a key part of changing a location's microclimate. The use of appropriate landscaping minimized the amount of direct sunlight striking and heating up building surfaces. In a solar-passive design, it is the optimum technique to create a buffer for heat, sun, noise, traffic, and airflow, or to divert airflow or exchange heat. It keeps heat from the ground or other surfaces from entering a structure by reflected light. Furthermore, through evaporative -transpiration, the shade provided by trees lowers the air temperature of the microclimate surrounding the building. Roof gardens that are well-designed can help to minimize heat loads in a structure. (Hasim Altan, 2016)

Shading

Shading is the essential passive strategy which is used to break the direct sunlight in the building. Buildings and outdoor places that are shaded help to reduce temperatures, increase comfort, and save energy. External shade systems provide the most effective sun protection, limiting up to 90% of heat gain. (Akande, 2010)

III. CASE STUDIES

3.1 SIDBI Head Office Lucknow

This is a project of central government which has the department known as small scale development bank of India. Which provides the loan to small scale industries. This building was took over by SIDBI in 2003.(Figure-1)

The building consists of G+8 floors with the total floor areas of 5316 sqmt. It consists of on ground parking with both covered and opened spaces.it has doubled heighted entrance with the reception and waiting area. The total space arrangement in each floor is divided into three zones working zone, service area and toilet area the working area consist of cellular plan. The cabins are separated from one another with the aluminum and glass partitions. The connectivity and accessibility of each cabin is through the passageway.

Figure-1 view of building from Ashok Marg .

Table -1 SIDBI details

Case study-1	SIDBI
Building Parameters	
Location	15 Ashok Marg civil lines, Lucknow, Uttar Pradesh
Climate	Composite
Orientation	W-E
Age	It was acquired by SIDBI in 2003
Building type	office
Total Built-up area	5316 sqmt
No. of Floors	G+8
Floor to Floor height	3.5
Occupancy (hr)	10
Materials	
Wall	18mm plaster+230mm brick wall+20 mm glaze glass(west façade) +12 mm inner plaster
Roof	40 vitrified tiles+150mm RCC slab
window	UPVC openable window with 6mm tint glass
WWR%	26
Window Sill(m)	0.9
Window height(m)	1.5
Energy consumption and equipment's	
Total energy consumption Annual (KwH)	914352
Type of HVAC	Fresh air louvre-controlled ventilation system
HVAC load (KwH)	502,893.6
Type of lighting	LEDs and fluorescent lamps
Lighting load (KwH)	246,875.04
Other loads (KwH)	164,583.36

3.2: UTTAR PRADESH RAJKIYA NIRMAN NIGAM (UPRNN)

Uttar Pradesh Rajkiya Nirman Nigam limited is an undertaking of government of Uttar Pradesh which was established in august 1975.Its execute the construction work, awarded by government, semi government and other undertakings in form of deposit works; through tender participation with speed, quality and economy. This building was established in 1992. (Figure-2)

The building consists of G+8 floors with the total floor area of 3320 sqmt.It consist of on ground parking with both covered and opened spaces.it has the double heighted reception and waiting area. The total space arrangement in each floor is divide into four zones i.e., working zone, service area, toilet area and courtyard. It consists of cellular planning the interior periphery of the building has adjacent cabins which area connected through the 1200 mm wide passage adjacent to courtyard.

Figure-2 View of building from Mandi parishad road

Table -2 UPRNN details

Case study-2	UPRNN
Building Parameters	
Location	Vishweshswariya Bhawan opposite RML hospital, Vibhuti Khand, Gomti Nagar Lucknow
Climate	Composite
Orientation	N-S
Age	1992
Building type	office
Total Built-up area	3320 sqmt
No. of Floors	G+8
Floor to Floor height	3.3
Occupancy (hr)	10
Materials	
Wall	Grey and white ACP sheets +230mm brick wall +12mm plaster
Roof	40 vitrified tiles+150mm RCC slab
window	Aluminum z-section openable window with 6mm tint glass
WWR%	20
Window Sill(m)	0.9
Window height(m)	1.2

Energy consumption and equipment's	
Total energy consumption Annual (KwH)	415104
Type of HVAC	Split ACs and window ACs
HVAC load (KwH)	189591
Type of lighting	LEDs and fluorescent lamps
Lighting load (KwH)	147812
Other loads (KwH)	77701

(Farheen Bano1*, 2020)

3.3: LUCKNOW DEVELOPMENT AUTHORITY (LDA)

Lucknow development authority is an autonomous body established under department of housing and urban development, group. (Figure-3) Prime responsibility of the development authority is to supervise and ensure the implementation of master plan for Lucknow city.

The building consists of G+11 floors with the total floor areas of 8766 sqmt. It consists of on ground and basement parking. It has single heighted entrance with the reception and waiting area. The space arrangement is segregated into three zones on each floor i.e., working zone, service area and toilet area the working area consist of cellular plan and open plan. The cabin are separated from one another with the brick partitions wall open areas consist of particle board partition with 1200 mm height. The connectivity and accessibility of each cabin is through the passageway.

Figure-3 view of building from Gomti Nagar bypass Road.

Table –3 LDA details

Case study-3	**LDA**
Building Parameters	
Location	Sector 38 A,2A, Gomti Nagar Ext. Bypass Road Vipin Khand, Lucknow- Uttar Pradesh.
Climate	Composite
Orientation	E-W
Year of completion	2009
Building type	office
Total Built-up area	8766 sqmt
No. of Floors	G+11
Floor to Floor height	3.6

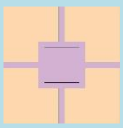
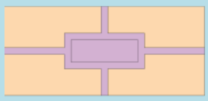
Occupancy (hr)	10
Materials	
Wall	18mm plasater+230mm thick brick wall+12mm plaster
Roof	40 vitrified tiles+150mm RCC slab
window	Aluminum openable window with 6mm reflected glass
WWR%	23
Window Sill(m)	0.9
Window height(m)	1.6
Energy consumption and equipment's	
Total energy consumption Annual (KwH)	1297374.2
Type of HVAC	VRV
HVAC load (KwH)	661185
Type of lighting	LEDs and fluorescent lamps
Lighting load (KwH)	271825
Other loads (KwH)	364364.19

(Farheen Bano1*, 2020)

IV. SIMULATION

The building type that is considered for simulation are generic office building shapes which are square, rectangle and rectangle+ courtyard. These shapes were derived from the case studies and literature studies. The areas of the office workspace and circulation is separated. circulation and services area is considered as the 20% of the building area. The building for simulation is designed for the capacity of 810 peoples and the total area was considered as 8100 sqmt according to Ashrae as 10sqmt area is required per person.

Table -4 Static and dynamic parameters for simulations

parameters	cases
Building shape parameters	**1.**  30x30 / **2.**  45x20 / **3.**  44x25
orientation	NS/ EW/ NE-SW/ NW-SE
Building footprint (m^2)	900
Total floor areas (m^2)	8100
No. of floors	G+8
Floor height(m)	3.6
S/V ratio	0.19 / 0.20 / 0.24
Windows parameters	
sill	0.8
windows height	1.5
Total WWR	15/ 20/ 25/ 30/ 35/ 40
Shading device	450mm projection

Building envelop material	
Wall (inner to outer)	18mm plaster +230 mm brick + 12 plaster
Roof	40 tiles +150 mm RCC slab
Window	Single clear 6mm glass
Shading	450 mm concrete projection
occupancy	
No of occupants	810
Area per person(m^2)	10
Working hours	9am – 5pm (8 Hours)
Energy and Equipment	
Energy	Electricity from grid
HVAC	VAV, Dual duct, Water-cooled Chiller
COP	2.0
lighting	suspended
Working plane height(m)	0.8
Normalized power density	4 (w/m2-100 lux)
Controlled type	linear

4.1 Case-1

Case 1 consist of a square plan of 30x30 meters in which WWRs were 15,20,25,30,35,40 and orientation were NS and NE- SW. The calculated s/v ratio for this building was 0.19 .12 simulations were performed in this case data is graphically represented in form of bar graphs.

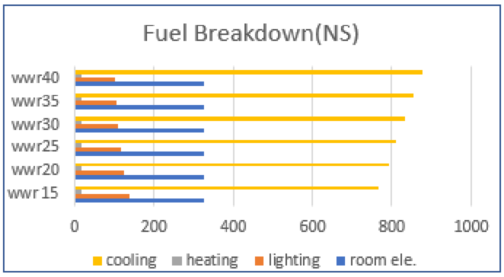


Figure-4. fuel breakdown for NS orientation

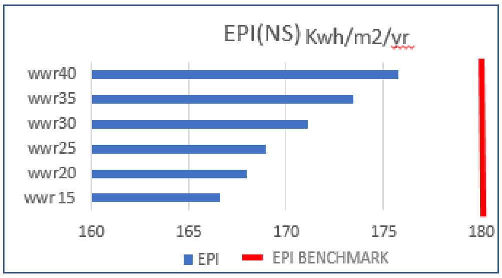


Figure-5. EPI for NS orientation

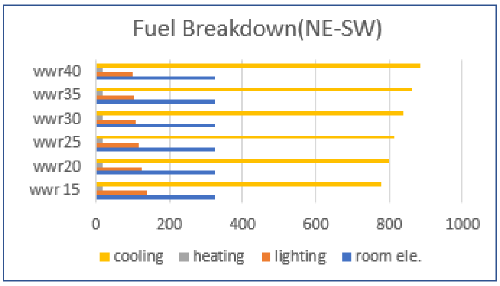


Figure-6. fuel breakdown for NE-SW orientation

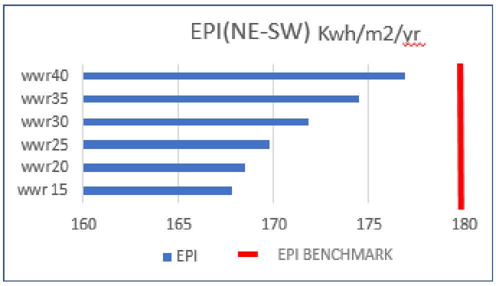


Figure-7. EPI for NE-SW orientation

4.2 Case-2

Case 2 consist of a rectangular plan of 45x20 meters in which WWRs were 15,20,25,30,35,40 and orientation were NS,EW, NE-SW and NW-SE. The calculated s/v ratio for this building was 0.20. Total no. of simulations that were performed in this case are 24 and data is graphically represented in form of bar graphs.

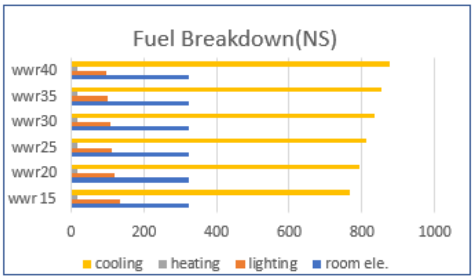


Figure-8. fuel breakdown for NS orientation

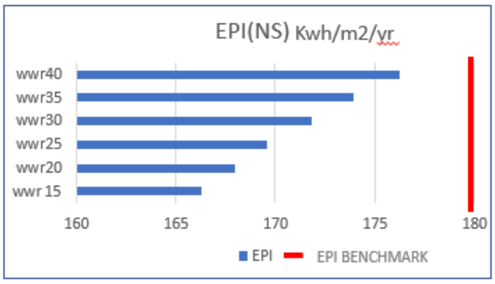


Figure-9. EPI for NS orientation

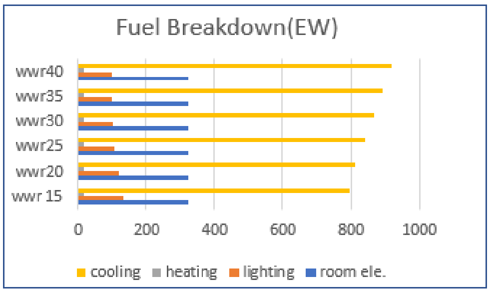


Figure-10. fuel breakdown for EW orientation

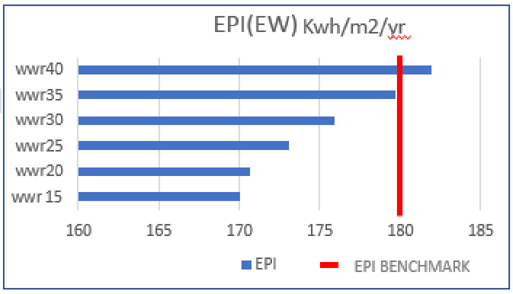


Figure-11. EPI for EW orientation

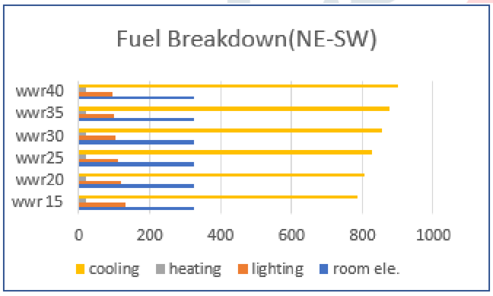


Figure-12. fuel breakdown for NE-SW orientation

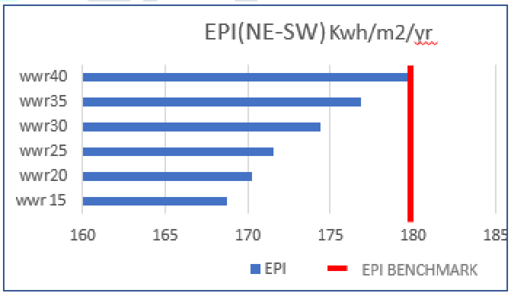


Figure-13. EPI for NE-SW orientation

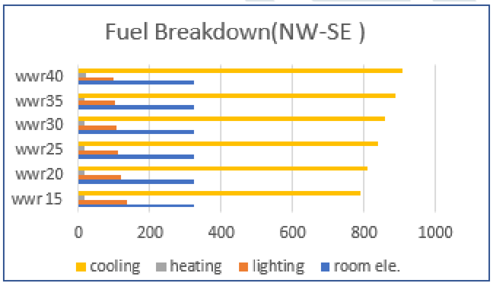


Figure-14. fuel breakdown for NW-SE orientation

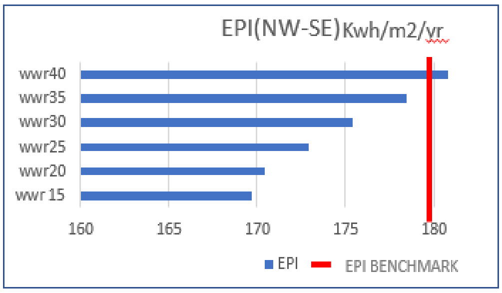


Figure-15. EPI for NW-SE orientation

4.3 Case-3

Case 3 consist of a rectangular + courtyard plan of 44x25 meters with courtyard of 10x20 meters in which WWRs were 15,20,25,30,35,40 and orientation were NS, EW, NE- SW and NW-SE. The calculated s/v ratio for this building was 0.24. Total no. of simulations that were performed in this case are 24 and data is graphically represented in form of bar graphs.

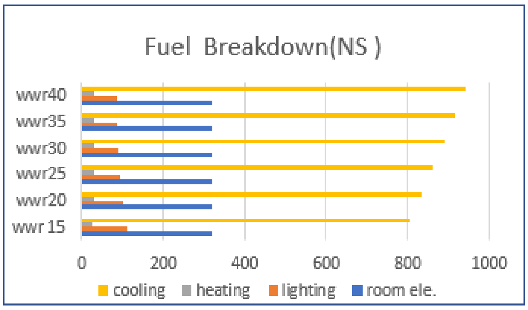


Figure-16. fuel breakdown for NS orientation

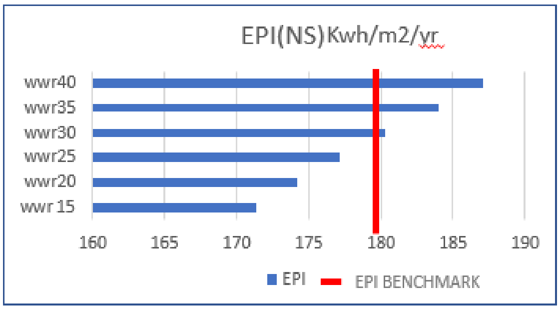


Figure-17. EPI for NS orientation

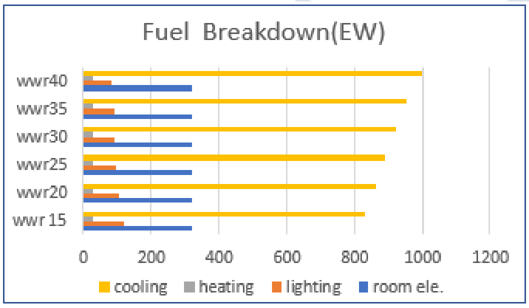


Figure-18. fuel breakdown for EW orientation

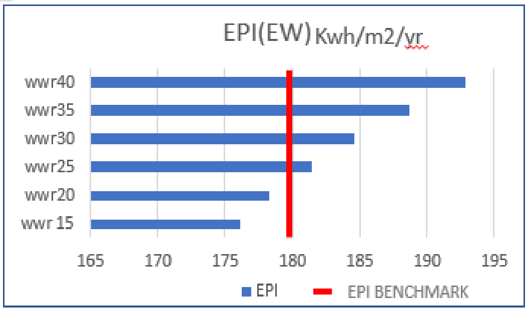


Figure-19. EPI for EW orientation

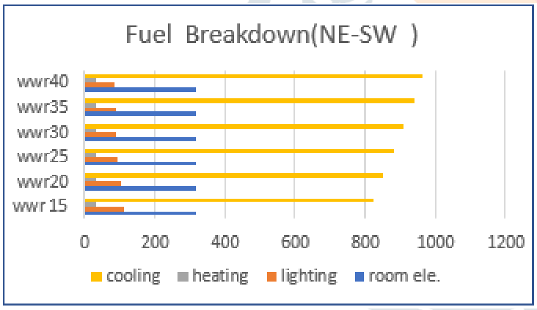


Figure-20. fuel breakdown for NE-SW orientation

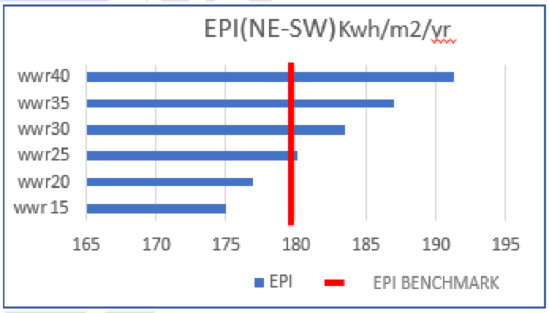


Figure-21. EPI for NE-SW orientation

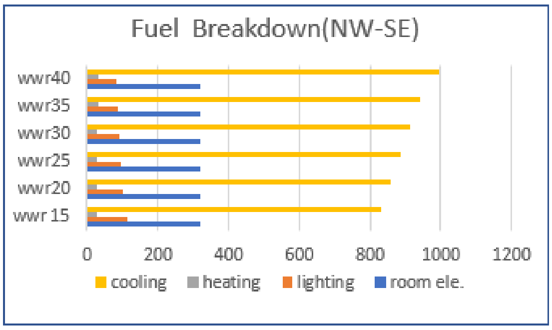


Figure-22. fuel breakdown for NW-SE orientation

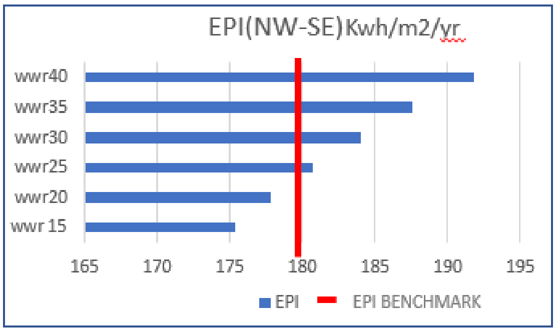


Figure-23. EPI for NW-SE orientation

V. RECOMMENDATION

- Compact form with low S/V ratio is recommended it should be as low as possible to minimize heat gain as compact plans have greater thermal efficiency as a square plan is more efficient than a rectangular one.
- The moderately compact internal planning will be of benefit for most of the year.

- Vertical shading devices protect from the sun at the sides of the elevation such as east and west sides.
- Horizontal shading devices protect from the sun at high angles and opposite to the wall to be shaded such as North and South sides. A combination of horizontal and vertical shading devices protects from the sun in all directions.
- Good ventilation is obtained when building opening is in the opposite pressure zone since natural ventilation relies on pressure that will help in the air flow.
- Glazing area should be reduced as long as it does not affect the uniformity of day light distribution in a building.
- Low solar heat gains coefficient (SHGC) materials should be used.
- Materials with high R value should be considered.
- Location, sizing and glazing of windows can be used judiciously to reducing the cooling load, achieving a balance between daylight penetration and heat gain is required a careful calibration between visual and heat transmission qualities of glazing and orientation.

VI. CONCLUSION

Generic building shapes that were derived from case studies and literature studies were simulated. The WWR were considered from 15% to 40% at the interval of 5% with all the orientation and three cases. Simulation stated that, as the WWR is increased the EPI also started increasing total fuel breakdown was monitored in each simulation. Fuel breakdown resulted that maximum energy that was consumed was by cooling system, Room electricity remain constant in all the cases, heating system also nearly remain constant as it showed very slight variation.

In terms of orientation the North-South orientation can be considered as the best orientation as in all the three cases the EPI was favourable. The S/V ratio also has the great impact on the energy efficiency of the building. It was observed that in all the three cases as the ratios were 0.19,0.20,0.24 that were of square, rectangle, rectangle + courtyard the EPIs of case-3 were high as compared to the other two cases. So it can be stated that the S/V ratio is directly proportion to the EPI. The case-1can be considered as the best case because it has all the EPIs in all the direction with favourable result.

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