International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 10 | Oct 2021 www.irjet.net p-ISSN: 2395-0072

# Passive House- The Future of Green Building

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**Abstract -** *In this study we examine the concept of Passive House in India. Passive House is a building which is planned and built with modern techniques and building materials which maintain a comfortable temperature within the building using climate to get the optimum benefit and eliminate independence on mechanical systems of cooling and heating. The simulation is done for a standard building design on Energy 3D software. Building energy consumption and orientation is studied for cities under different climatic zones. The changes in properties of material and effect of shading are monitored. Methodology and results show the benefit of implementation of passive design strategies in building and an economic analysis presented proves the cumulative cost of annual expenses makes it more feasible in the long-term.*

***Key Words*: Passive House, Construction Techniques, Daily Net Energy Consumption, Economic Analysis**

## 1. INTRODUCTION

Passive House is a standard of energy efficient building which helps to reduce building ecological footprint and requires minimal to negligible space heating or cooling. It is considered as a Green Building due to reduced emissions and energy savings achieved during the life cycle. Passive Houses have a functionality that allows for keeping energy reserves related to space heating and cooling which are higher compared with the typical building and average new builds. They make reasonable use of natural sources like sun, heat recovery system, internal stored heat, thereby making conventional heating systems unnecessary throughout the year even in the coldest of winters. During warmer periods in the year the building makes use of passive cooling techniques like strategic shading to keep the environment comfortably cool without the use of mechanical ventilation. Special window glasses, building envelopes incorporating a highly insulated roof and floor slab, as well as highly insulated exterior walls, keep the desired warmth in the house.

The building simulation is done on Energy 3D software which is an engineering tool to design, analyze and construct green buildings. It uses computational physics and weather data to accurately model a building according to parameters such as location and day. It uses artificial intelligence and is capable of generating time graphs and heat maps with automatic assessment and engineering optimization.

Some basic requirements of Passive House are strong thermal insulation, well insulated and fitted windows, ventilation heat recovery system, maintained air tightness in building and absence of thermal bridges. The need of Passive House Technology today is mainly due to the concern regarding increased carbon emissions. Here Passive House comes with many advantages to list as the system works nearly off the power grid and governments have started to give tax credits and grants in support of its social recognition. The proven results of efficient builds, long lasting quality and comfortable housing is an exception to conventional construction.

**Fig -1:** Passive House Model

The figure is an illustration of typical architecture involved in a passive house model designed on Energy 3D. A two storey structure of area $123m^2$ is developed having twelve windows, enclosed in brick masonry and made air tight with plaster, having excellent thermal storage and soundproofing characteristics. Sloping roof is considered for energy efficiency. The building orientation is a longer dimension placed on the East-West axis.

## 2. CONSTRUCTION TECHNIQUES

The Passive House comes in different forms using patterns of layout, forms and fabric with stringent construction and design standards.

### 2.1 Building Orientation

The building orientation is a factor to determine the amount of radiation it receives. It is decided with respect to air patterns which allow natural ventilation. Particularly for India Sun moves from East to West in the Northern Hemisphere hence more exposure of Sun is to East and West.

Hence orientation which has a longer part in the North – South axis is undesirable for Hot Areas.

Tropical climate in India shows that keeping the longer axis of the building in the East or West direction, the longer dimension of the home faces will be more likely to gain the maximum solar radiation for the same reason; the kitchen and the living room must be located into this part of the building. When the sun comes to the south it is at high Altitude and the solar radiation can easily be cut off by using horizontal shading.

## 2.2 Plan Form

The Plan form of the building affects the airflow in and it. This could either let in and or hinder natural ventilation. The perimeter to area ratio of a building is an important measure to determine heat loss and heat gain. Observing the direction of air movement, the plan form can be determined to create high pressure and low-pressure areas in the building. The openings that connect high pressure to low pressure areas will cause effective natural ventilation in the room. Greater the perimeter and area ratio, greater the radiation and heat gain during the day and the greater heat loss at night. Smaller the ratio indicates less heat gain during the day and loss during the night. In hot & cold climates, the perimeter to area ratio shall be minimum to ensure minimal heat gains and loss. For warm-humid climates, maximum perimeter to area ratio can help to maximize air movement.

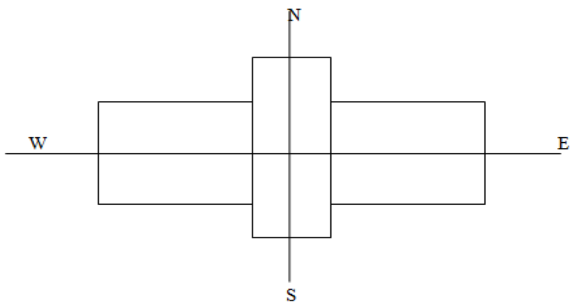



**Fig -2:** Orientation of Street

## 3. DESIGN ELEMENTS

Each Element of Design in Passive house is made to work with other by appropriately studying the surrounding conditions.

## 3.1 Water Bodies

Water Bodies are effective means of evaporative cooling because water has a high specific heat capacity and can absorb a comparatively large quantity of radiation. It can even be used as a heat storage tank which can increase the humidity for warm-humid climates.
Water bodies shall be placed on a route where the air is entering the building in the direction of wind, the air can pick up moisture from the water body which is suitable in a Hot dry climate area. But not the same procedure is followed in Cold climate regions.

## 3.2 Vegetation

Vegetation can absorb radiation and affect cooling while causing humidity and affect the daylight entering or cause glare. Planting a Deciduous Trees towards South, so in Summers these deciduous trees could shade the building & control direct radiation of day lighting. While in winters they shed their leaves and allow sunlight and daylight to penetrate inside the building.

**Fig -3:** Vegetation according to shadow analysis

Courtyards & Verandahs used as shaded elements are quite efficient to store cooler air in hot climate as it tends to collect in the court and is a highly preferred design element in Warm Humid climate because it induces air movement due to differential heating. For Hot climate, integrating vegetation as gardens, roof gardens, plantations are desirable into the building to reduce heat gain. Shaded courtyards would lower air temperature. For Cold climates, Greenhouses and glass boxes are effective heat traps to enhance heat gain. For Humid climate, they aid in ventilation and wind-catchers may be employed only in case of strong and cool breezes.

## 3.3 Solar Irradiance

The figure shows power per unit area received by building due to the solar exposure also called as solar irradiance, the model is simulated for Indian climatic conditions varying from temperate to tropical and lying in lower latitudes. The exteriors experience a Diffused horizontal irradiance. The Diffused horizontal irradiance is scattered radiation due to cloudy periods or particles in the atmosphere. The solar panels come in use to convert the diffused to normal radiation.

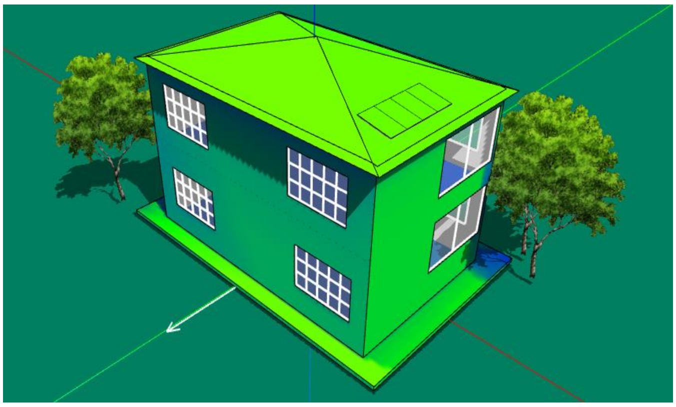


**Fig -4:** Simulation for Solar Irradiance

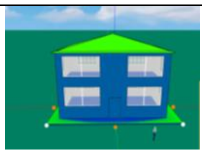
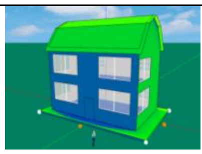
### 3.4 Walls

Walls receive incident radiation from the Sun, so their material is a major factor to consider heat flow studies. Wall construction designs like Cavity walls which have air spaces between the two layers to reduce heat transmission are sustainable. The material used to construct walls shall be of low U-value in hot climates. Trombe walls can be used as thermal mass for effective means of heat gain in cold climates. For a mechanical insulation and stone insulation U-value is less while for concrete it's more than them.

### 3.5 Roofs

Roof materials and shapes help to determine the amount of heat transfer inside through the roof or outside and also the time taken for this heat transfer to take place. While selecting roof materials the study of the amount of heat absorbed by the material and transmitted, with the time required for this transmission must be noted.

**Table -1:** Suitability of Roofs by Climate

| FLAT ROOF | SLOPING ROOF | DOMICAL ROOF |
|---|---|---|
|  **Fig -5:** Flat roof |  **Fig -6:** Sloping roof |  **Fig -7:** Domical roof |
| In areas of maximum exposure to Sunlight | In areas of more or very less sunlight | In areas of high solar heat gain |
| For cold and dry regions | For high precipitation and cold regions | For extreme hot regions |
| Eg: Leh-Ladakh, Spiti Valley, Guwahati | Eg: North Eastern States | Eg: Rajasthan, Gujarat |

In hot & cold climates, the roof should have a low transmittance value to ensure maximum heat gain and heat loss respectively. Here insulation will minimize the heat stored in the roof. For construction three different types of roofs are considered in common use with each having a different purpose.

## 4. FENESTRATION

Fenestration is an important element of the Building because it allows and affects the movement of air and hence temperature, it also controls the amount of air ventilation or ventilation required. The pattern and configuration include area, shape, location & relative positioning which affects the air movement in the structure, daylight & glare indoors. Location of the opening in walls and its area can affect ventilation & distribution of the light indoors. On the basis of climates and materials they are further classified.

### 4.1 Arrangement and Configuration

Windows for hot climates shall be appropriately shaded, smaller area, high opening or ventilators as effective heat vents. Looking at the physiological objective in extremely hot, dry and cold climates, interaction of the outdoors with the indoors as far as heat exchange is concerned needs to be minimum. Hence, we prefer smaller to reduce convection. Material used is wooden shutters as we don't want daylight and radiation and also don't want air movement.

For warm-humid climates appropriately sized windows to facilitate ventilation accompanied by appropriate shading devices must be used. However, for movement size of the fenestration is preferred to be large. For cold climates windows shall be large sized and unshaded but air-tight made of insulated Glass, Double glazed window which allows a lot of radiation to come in but blocks the air. Windows should be oriented towards the sun that is south facing and also be inclined at a certain angle so that sunlight can penetrate. For composite climates adequate design of shading devices is required to cut off summer sun, allow winter sun and facilitate ventilation. Windows as a combination of high windows with baffles, low windows along with baffles and light, reflective interior finishing can help distribute light inside a room uniformly.

### 4.2 Orientation

The amount of radiation incident on the opening depends on the orientation of fenestration. It is a major component used to increase or decrease natural ventilation with respect to the air pattern. In hot-dry climate fenestration must face north and in cold climates it shall face the south. For humid climates, it shall be within 45° of the perpendicular to direction of airflow. The inlet and outlet should be in a staggered pattern which will enable to maximize airflow.

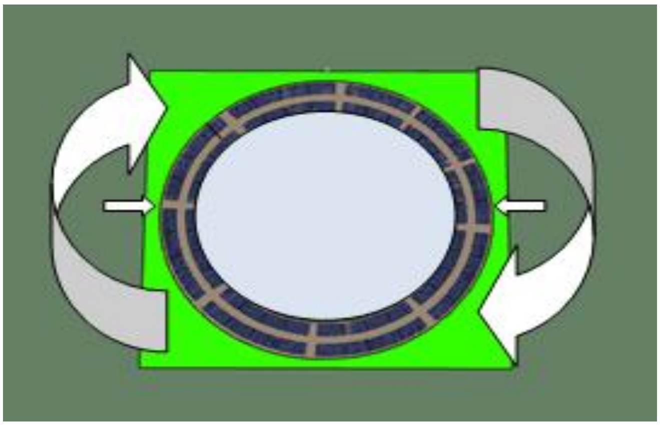


**Fig -8**: Window in East or West

Window in East or West shows that it will maximize heat gain in morning and evening as sun would be at lower altitude which will increase Sunlight penetration. Therefore, windows should be oriented properly.

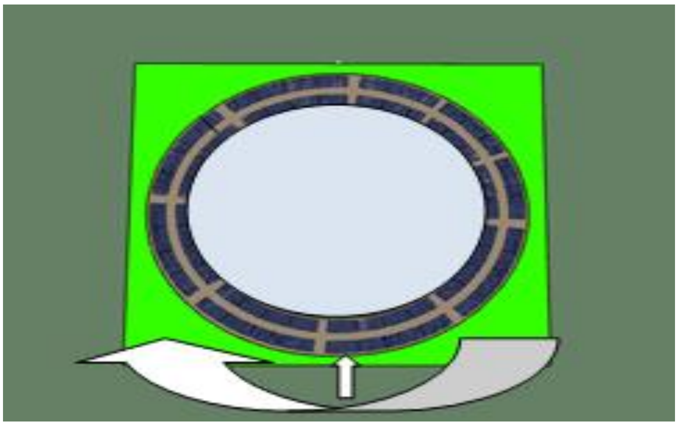


**Fig -9:** Southern Glazing

For colder climates Southern Glazing is preferred to minimize the heat gain.

### 4.3 Controls and Shading Devices

Based on orientation and sun-path diagrams these shading devices can be arranged. Most commonly used are Shades, both vertical & horizontal that control radiation and heat gain. The projection can be modified and designed to cut-off the sun's incident rays by using solar azimuth and altitude for overheated & underheated periods. Then Light Shelves are horizontal projections functioning as a horizontal shade, having an upper reflective surface which brings more amount of light in the room. They can be placed inside, outside or partly inside or outside over a window.

Fly-wire nets also reduce the velocity of air coming indoors as well as a control device for insects. For hot climates, glazed surfaces and windows are needed to be shaded from the sun. In cold climates light shelves can be beneficial over windows in utilizing the low sun angle. For composite climate shades help to cut-off the sun in hotter months yet allow in the cold to enhance air velocity.

## 5. DAILY NET ENERGY CONSUMPTION

The two factors used in comparing energy output are the U-value and Solar Heat Gain Coefficient. U-value signifies thermal transmittance or the rate of transfer of heat in matter while Solar Heat Gain Coefficient (SHGC) is the measure of heat passing through a window. Higher the U-Value more is the solar heat gain coefficient. For classified materials in different climate types a city is chosen and daily energy analysis is done.

### 5.1 Simulation for Door and Windows

The model is tested after changing the materials used in doors and windows to check for the variation in daily net energy consumption.

**Table -2:** Result for Daily Energy analysis of Building

| CLIMATE TYPE | CITY | CALCULATED DAILY NET ENERGY (in Kwh) | | CALCULATED DAILY NET ENERGY (in Kwh) | |
|---|---|---|---|---|---|
| | | Clear Glass SHGC -0.66 | Triple Glazing/ Tinted Glass SHGC-0.39 | Uninsulated Metal doors | Insulated Metal and Wooden doors |
| Hot and Dry | Ahmedabad | 164.3 | 129 | 134 | 130 |
| Warm and Humid | Mumbai | 95 | 76.6 | 79.4 | 72 |
| Cold | Guwahati | 131.4 | 99.1 | 102 | 100 |
| Composite | Indore | 120 | 91.5 | 94 | 92 |
| Moderate | Bangalore | 87.7 | 61.6 | 63 | 62 |

The results show that Daily Net Energy Consumption drastically reduces when clear glass (U value-7.38W/m2) is replaced with tinted double or triple glazing panes (U value-1.42W/m2). On the other hand, there is a gradual decrease in energy consumption when Uninsulated metal doors (U value- 6.81W/m2) are substituted by Insulated metal doors or wooden doors. Cost of building remains the same but daily net energy varies.

### 5.2 Simulation for Solar Panels

The solar panels are photovoltaic cells that use the sun's energy to generate current electricity. The solar photovoltaic cells have a life span of 25-30 years and a single solar panel saves upto 0.7Kwh. For simulation a solar panel rack of four cells is used.

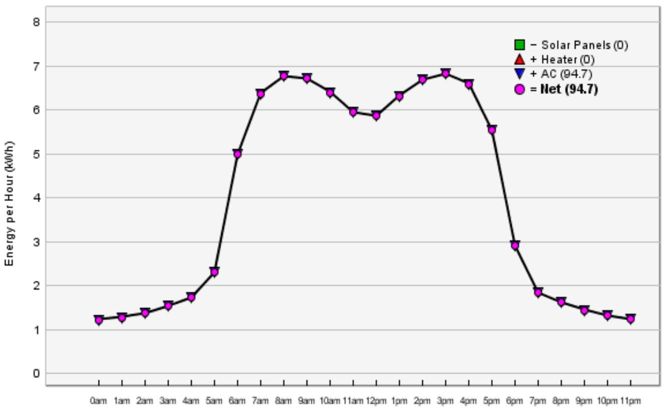



**Chart -1**: Energy Analysis without solar panels

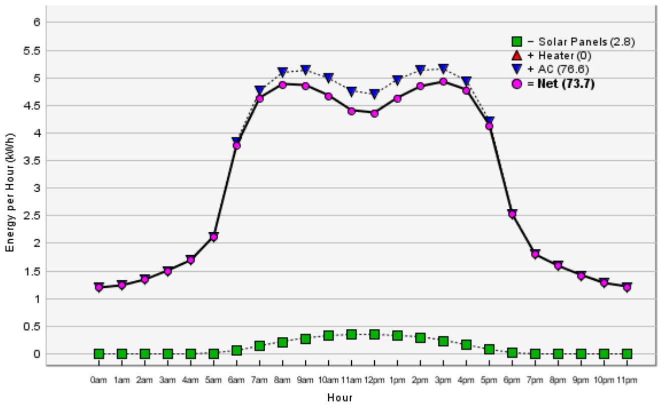



**Chart -2**: Energy Analysis with solar panels

The energy saved per day is 20.5Kwh as observed in the graphs.

## 6. ECONOMIC ANALYSIS

Economic analysis is done based on economic fluctuation information analyzed on Energy 3D software which is used to determine the thermal losses in buildings. Investment goes higher due to the improved insulation and ventilation system. The cost of additional investment is paid back in around 3- 6 years depending on elements utilized. In the analysis the overall upfront investment for 25 years in the four panels is $4080 for, so per day it costs approximately $0.45.The cost of electricity varies state to state around $0.054 to $0.12, considering minimum and maximum limits the cost saved is $0.67 to $2.06 per day. This proves the higher returns on investment. Passive roof technologies like cool paint, RB type bricks stacked, air gap and EPS foam if used in project will have smaller payback period and are of higher importance in passive houses.

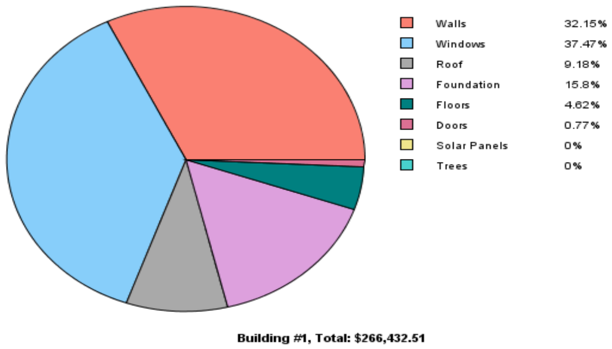



**Chart -3**: Cost Analysis without passive strategy implementation

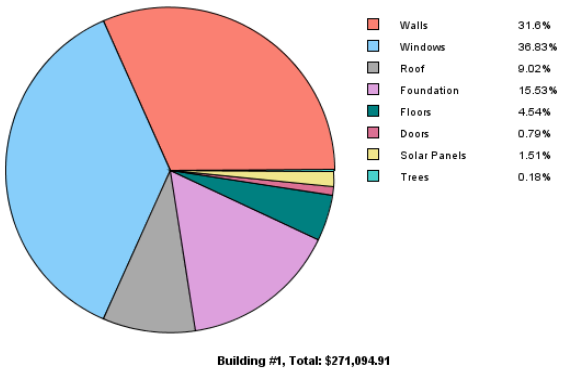



**Chart -4**: Cost Analysis with passive strategy implementation

Before implementing the passive house elements in the project, the cost is $266432.51, the additional insulation, ventilation system and solar panels account for extra tariff and project cost amounts to $271094.91. The shorter payback period and market liquidity provided by capital investment is a good reason to consider alternatives.

## 7. CONCLUSION

Passive houses are a step forward to help reduce energy consumption at the same time meeting demands of conventional constructions. It gives impetus to a healthy environment using some innovations in design. Expensive initially in the developing country scenario but cost efficient if people realize the importance. India is still way behind compared to other nations in implementing this technology and the study serves the purpose to show the benefits and small initiatives that can be taken for comfortable living.

## REFERENCES

[1] Wolfgang Feist & Rainer Pfluger & Wolfgang Hasper (2019) Durability of building fabric components and ventilation systems in passive houses has in published at https://doi.org/10.1007/s12053-019-09781-3

[2] Ar. Dhenesh Raj , Ar. Bindu Agarwal Journal of Civil Engineering and Environmental Technology; Online ISSN: 2349-879X; Volume 1, Number 3; Passive House and Nearly Zero Energy Buildings published at http://www.krishisanskriti.org/vol_image/03Jul20150 1070213.pdf

[3] Rania E.Ashmawy a, Neveen Y. Azmyb (2017); Conference: Al Azhar 14th International Conference (AEIC) on Engineering , Architecture & Technology https://www.researchgate.net/publication/327623184 _Buildings_orientation_and_it's_impact_on_the_energy_c onsumption

[4] Manoj Kumar Singh, Sadhan Mahapatra, S.K. Atreya (2011); Solar passive features in vernacular architecture of North-East India published at https://www.researchgate.net/publication/230642012 _Solar_passive_features_in_vernacular_architecture_of_N orth-East_India

[5] Mragank Gupta, Climate Responsive Architecture Design Matrix About the Matrix A Design Tool B published at

https://www.academia.edu/25665032/Climate_Respon sive_Architecture_Design_Matrix_About_the_Matrix_A_D esign_Tool_B

[6] Fundamentals of Climate Responsive Buildings-1, Sustainable Architecture, Department of Architecture and Planning ,IIT Roorkee https://nptel.ac.in/courses/124/107/124107011/