OPTIMIZATION OF ENERGY USE INTENSITY IN A DESIGN-BUILD FRAMEWORK

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Abstract

The demand for sustainable building is increasing with minimal environmental impact, with increasing energy cost and more concern about environmental issues. In developing countries building does not provide sustainable condition, so the energy efficiency of the building is less. The objective is to analyze the criteria for energy efficiency, resulting in a series of feasible solution that can minimize the usage of energy and thereby reducing the energy demand and providing thermal comfort for the building occupant. And necessary improvement is performed in the building and the modeling is carried out for optimizing energy efficiency. Modeling is done qualitatively to ensure economical factors of building energy efficiency. By optimizing building energy use intensity, it offers sustainable savings in energy consumption. Building fabrics determine the energy use intensity in a residential building. By optimizing the building envelope the sustainable condition is obtained. Reducing energy use intensity from home will lower the energy production from fossil fuels. The building energy performance depends on the energy use intensity; the parameters which determine the energy efficiency of buildings are thermal comfort, water and energy. The simulation program guides the retrofitting of residential building, by optimizing the design-built framework the efficiency is improved in an economical way.

Keywords: *Sustainable building, energy efficiency, thermal comfort, energy demand, energy performance, energy use intensity.*

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1. INTRODUCTION

The demand for energy in developing countries is becoming alarming, whereas the means of electricity production remains limited. Due to climatic change, high temperature and humidity, significantly increases the use of air conditioners to attain better thermal comfort. Depletion of fossil fuels and increase in fuel cost leads to an electricity shortage. And, the energy crisis made an effort in reducing the overall energy consumption in building sector.

The residential sector in India consumes 37% of energy reflecting the importance of the sector in the national energy scenario. Electricity consumption is mainly influenced by seasonal variation in residential building. Most of the energy consumed for cooling, electrical appliances and water heating, these depend mainly on the ambient temperature.

Many cities in India experienced rapid urban growth without any references to the evolving urban environment. This puts a pressure on the energy demand in the country. The demand for comfort conditions in buildings are significantly increased as a result of exposure to uncomfortable outdoor temperature [1].

In the context of Vellore, overheated outdoor climate of the location has contributed to a lower indoor comfort. The buildings in tropical climate are overheated due to solar gain in the daytime through the building envelope [2]. The climatic conditions affect the temperature and air flow, which thereby affects the thermal comfort of the building. Due to the high intensity of heat transient from building envelope the residential buildings are subject to increase in cooling demand. By significant increase in thermal comfort can improve energy savings. Around of 50% of annual energy is consumed for air-conditioning with an average electric energy ratio of 100 kWh/m2 of floor space.

The aimed work will explore all possible parameters that can be modelled under the Energy Simulation program. On the guidelines of ASHRAE standards the Building simulation is done. ASHRAE standard specifies the test procedures for evaluating the technical capabilities and ranges of applicability of computer programs that calculate the thermal performance of the buildings and their HVAC systems. The ASHRAE includes weather data, instructions for building envelopes, Service water heating, and HVAC, Power, Lighting, and Equipment details.

Reduction of energy usage in the building has a positive impact on the environment; energy generation mostly has a negative impact on the environment. By reduction of building energy usage there is a positive impact on the economy for the building occupants. Over utilization of energy might deplete the environment and it concerns society, there will be a positive impact on the environment by reduction in energy usage.

The specific problems that signify the importance of energy efficiency in buildings are as follows, growing population, rising number of buildings, increased living standards, high energy usage and interrupted power supply. The research performance can provide further improvements in the design and knowledge of buildings within the sub-tropical climate. The actual research performance will determine the justification in the advancement of design and knowledge.

The four parameters considered such as design variables (geometrical dimensions of building elements such as orientation, roof, wall, window, door, etc.), material properties (thermal conductivity, specific heat, transmissivity, etc.) weather data (ambient temperature, solar radiation, wind speed, etc.) and building usage data (electricity, lighting, and etc.).

2. METHODOLOGY

The research analysis and methods broadly focused on different phases, in which the main work is divided. In the first step the recognition and annotation of technique are done by a theoretical framework. A methodology of DIN V 18599 series is followed in calculating the overall energy balance of the building. The next step is to propose improvements for energy efficiency of buildings. This part is accomplished by working with the simulation programs Climate consultant 5.4, HEED (Home Energy Efficient Design), Net Zero Energy Building evaluation tool and Ecotect analysis 2011. The following task is to calculate the improved building energy efficiencies, when necessary improvements are followed.

2.1 Climate, Site and Orientation

The proposed residential building is located on the geographical coordinates of 12°56’N, 79°20’E located in sub-tropical climate region, within the mean maximum temperature ranges from 28.2°C to 36.5°C and the mean minimum temperature ranges from 17.3°C to 27.4°C and relatively low rainfall [3]. Building orientation is considered according to the interaction with solar radiation as well as wind direction. The building orientation is north-south for habitable rooms. The kitchen receives the maximum amount of sunlight throughout the day. Prior to determining the energy balance, a building is divided into various zones.

2.2 Thermal Behavior of the Building

The maximum heat gain in the building zones is due to the interaction of solar radiation. The ambient temperature is higher than the indoor temperature; heat enters the building by convection. The outer surface of the wall will convert the incoming solar radiation to heat and will radiate it into the building zones. The heat gain of the building occurs by conduction, the inner zones of the building have temperature fluctuation by air leakage. Thermal performance of a building depends on the prevailing outdoor temperature.

The building zone comfort is improved by U-value and R-value, lower the U-value and larger the R-value better the insulation effectiveness. Most of the window openings are facing southern wall and thus it makes the maximum uncomfortable condition in peak summer [4].

The overall indoor energy balance is influenced by the building fabric, thus the thermal comfort of the zones is depended mainly on the thermodynamic process. The indoor air temperature increases through windows opening and indirectly by building component. The study building is accompanied by high solar radiation, high humidity and low velocity which results in thermal discomfort of the building zones in most part of the year.

Thermal comfort is achieved through ventilation, the total heat gain accounts for 25-28% through windows adding to infiltration. For thermal comfort, the optimum air velocity is 0.7 ms^{-1} at normal climatic condition. The ventilation rate will be less when the number of Air changer per hour (ACH) is less than the minimum value and thus indoor air quality will be poor. Maximum airflow provides an uncomfortable indoor environment. The window opening relies on occupant behaviour and it provides hygienic airflow in the building zones.

ASHRAE RP884 proposed the following algorithm:

$$Tcomf = 0.31 \times Ta,out + 17.8\ (°C) \qquad (1)$$

Where, Tcomf is thermal comfort, Ta,out is mean outdoor dry bulb temperature.

The relationship between indoor comfort and outdoor temperature has been expressed (ASHRAE 55-2004) in terms of the monthly mean of the outdoor temperature. Important variations of outdoor temperature occur at much shorter than monthly intervals. Adaptive theory suggests that people respond on the basis of their thermal experience, with more recent experience being more important [5]. A running mean of outdoor temperatures weighted according to their distance in the past may be used to characterize the response [6].

Feasibility comfort mainly depended on window to wall ratio, when feasible factor is greater than 0.25, then visual comfort is potential. The building visual comfort is determined according to the window opening. Window opening is more than lower the thermal comfort of the zone.

2.3 Water Conservation

The building is located in relatively lower rainfall region and ground water level is low. To pump required water, lots of energy is required; it depends upon the aquifer level. Lots of energy is utilized to procure, treat and store water, which increases the electricity consumption by reducing building energy efficiency.

Rain water harvesting is flexible and it provides a supplement to the regular water source. And it is used for non-portable purpose. The rainwater harvesting is not present in the building. The efficient use of rainwater can minimize water demand and thereby it improves the energy efficiency of the building. Water conservation varies according to the building location, so this factor varies the efficiency depending upon the climate.

2.4 Electricity Consumption and Demand

The annual electricity consumption of the building is high. The building mainly depends on the delivered energy from the central electricity grid. Around 2 to 4 hours of electricity shut down every day. Inverters are used in building to overcome the electricity shortage, the inverter consumes of lots of energy to charge batteries, and thus it increases the electricity consumption and reduces the building energy efficiency.

Energy intensity is a measure of the building energy efficiency. The standard of living determines the electricity consumption of the building. Electricity consumption varies with respect to season. The electrical appliances depend on the occupant living standard and thermal comfort.

2.5 Simulation Parameters

To perform the simulation certain parameter need to be finalized and set in the simulation program, such as the dimension and location of the proposed window, depth and pattern of the shading device and glazing specification (Visible Light Transmission), internal reflectance of floor/wall and ceiling, outdoor luminance and sky condition.

The procedure adopted for analysis is as follows to develop the model of the building, load the weather data as per the location of the building, assign building material properties, draw the analysis grid at a work plane height of 1200 mm from floor finish, Set the outdoor design sky condition data as per the climate data to be selected and start the simulation process as per ECBC.

3. RESULTS AND DISCUSSION

Based on the analysis done, the factor for each zone does not satisfy the recommended factor by Energy Conservation Building Code (ECBC) and Green Rating for Integrated Habitat Assessment (GRIHA).

As the total heat gain is positive, it represents the building heat transfer. During the May month, maximum value of heat is observed in the zones. The U-factor varies depending on the envelope element, as shown in table 1. By standard insulating the building thermal behavior can be optimized and which lowers the heat transfer from the outdoor environment. Maximum radiation is received in the south facing wall, during summer it attains a peak temperature.

The occurrence of thermal comfort in the building can be achieved below 27.46°C with considering the WWR. If WWR is minimized, the air flow would not be effective. The passive adaptive index of the building is 0.81, as shown in Fig. 1. The peak temperature would be 31°C, by window opening an air velocity of 0.6mps and thus temperature become 27.2°C and it is considered comfortable by ASHARE (American Society of Heating, Refrigerating and Air Conditioning Engineers). By window opening there is a chance of a decrease in thermal comfort, these can be optimized with adaptability index. Using predicted mean value (PMV) model the comfort zone value of the people in residential building is calculated, as shown in Fig. 2. Dry bulb temperature variation influences the comfort band.

Table -1: Building Envelope

Envelope element	Design case	
	Assembly structure	"U" Factor (Btu/h·ft2·°F)
Roof	As per ASHRAE 90.1.2007	0.063
Wall above grade	Cement Concrete Blocks	0.375
Wall below grade	NA	0.375
Floor	As per ASHRAE 90.1.2007	0.350
Glass	As per manufacturer catalogue	0.998

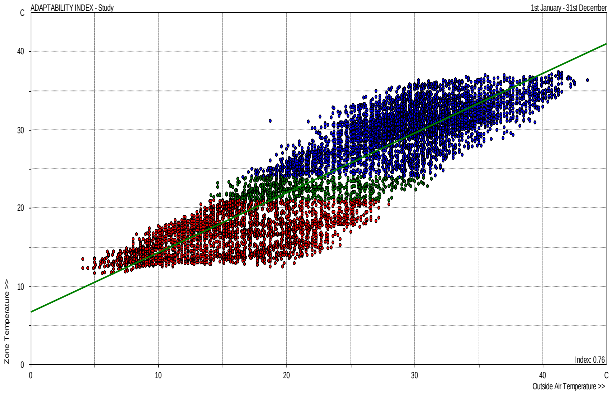

Fig -1: Adaptability index of the study building

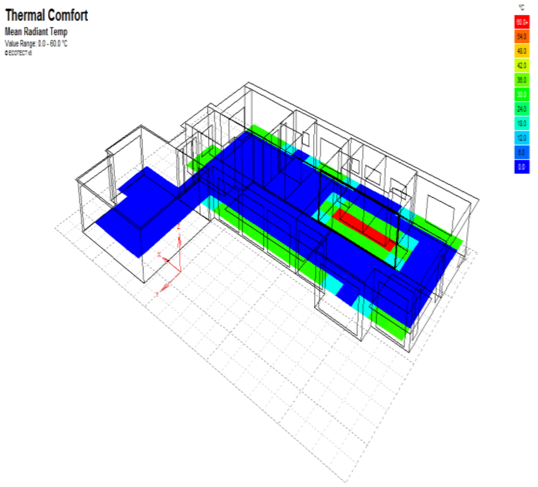

Fig -2: Thermal comfort of the study building using Ecotect analysis 2011.

Average daylight factor of the overall zones in a building is 2.34% and average day lighting level is 201.34. By providing proper visual comfort, the artificial lighting can be reduced in the building. Daylight factor depends on the window opening and the orientation. Windows on the south facing wall as higher visual comfort, when compared to the other wall facings. Due to obstruction the feasibility factor is less than 0.25 in the kitchen zone, by removing obstruction the daylight factor is 2.70% and for living zone it is 2.07%, as shown in Fig. 3 & Fig. 4.

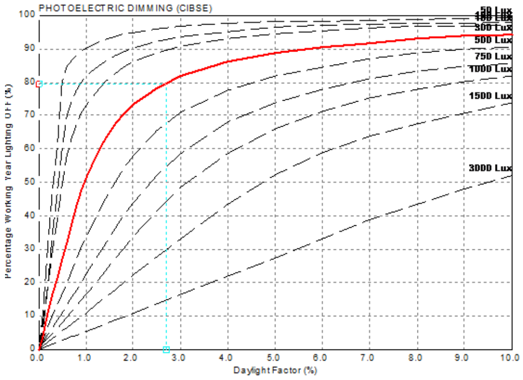

Fig -3: Daylight factor of the kitchen zone using HEED

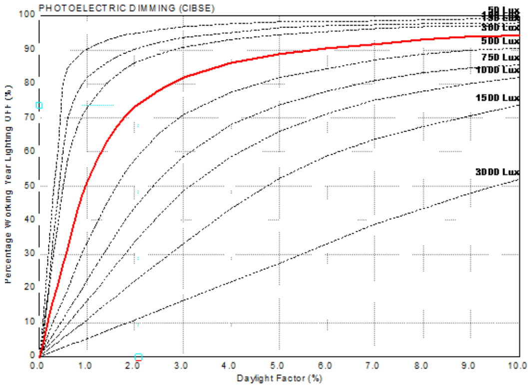

Fig -4: Daylight factor of the living zone using HEED

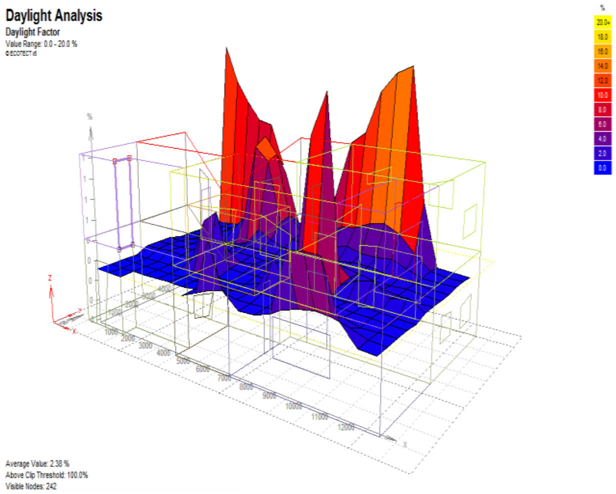

Fig -5: Daylight analysis of the study building using Ecotect analysis 2011

The daylight factor in the southern zone (living region) is higher, as shown in Fig.5. Thus the thermal comfort in the bedrooms is very poor. Thus, by optimizing the window wall ratio (WWR), the daylight factor can be optimized. Higher visual comfort in these zones leads to the utilization of mechanical cooling, thereby increases in energy utilization, by optimized WWR the energy efficiency is improved. Proper selection of glazing can reduce the heat transfer through the air flow.

A month by month assessment is complicated and thus separate primary energy factor is calculated for summer and winter of a year. The primary energy factors relating to the provision of delivering energy comprise all the factors of primary energy with all preceding activities. The energy chains are determined by modeling with these factors. The efficiency of building varies with respect to the ambient temperature and there is no much fluctuation of energy use intensity, it depends mainly on seasonal comfort. Fabric loss is high and which reduces the building energy efficiency, as shown in Fig 6. Sol-air gain is higher and which fluctuates the thermal comfort of the building, as shown in Table 2.

Table -2: Passive Gains Breakdown

Category	Losses	Gains
Fabric	71.50%	20.40%
Sol-air	0.00%	58.30%
Solar	0.00%	6.70%
Ventilation	21.10%	6.50%
Internal	0.00%	6.40%
Inter-zonal	7.30%	1.70%

By upgrading the building fabric and insulting it qualitatively improves energy performance of a building. The energy performance index (kWh/m2/year) for a non air-conditioned zone is 45 and for an air-conditioned zone is 135. Percentage reduction in energy performance compared to the benchmarked energy efficiency is 42.7%. Energy performance index of building is 34.13 kWh/m^2/year.

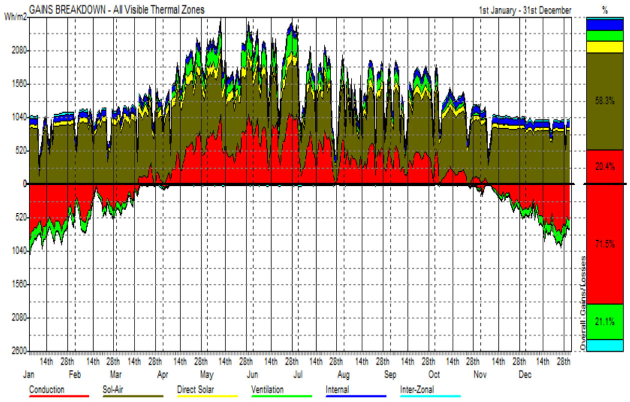

Fig -6: Passive gains breakdown of the study building

The annual energy performance of a building depends on the total area of the building. The energy balance is calculated in accordance with DIN V 18599 series, it interacts with the building energy usage and building factors considered within the building series. The energy quality of the building is compared with the measured energy rating in a qualitative manner. From the series, the primary and delivered energy of the particular building is optimized, as shown in table 3.

Table -3: Annual Energy Performance

Total area (m^2)	148.52
Total annual predicted energy performance (kWh)	8345.27
Energy performance Index (kWh/m^2/year) 24*7	34.13
Percentage reduction in energy performance compared to the benchmarked energy performance	42.78%

The energy need for cooling of the building is determined by iteration method. All energy sources are compared with a heat sink that depends on the building energy usage. The characteristics of each area served by building zone and it is grouped together and optimized to provide energy efficiency. The internal gain of the building fluctuates with respect to the building envelope. The series group the building zone with respect to the optimized condition.

The optimized building energy efficiency is 68.4% in peak summer and 77% in winter. By optimizing the building primary parameters, the energy efficiency is improved. The major loss of energy is due to building fabric, by proper insulation of the building envelope, the loss is being reduced. Residential building should be ventilated properly, to provide a better indoor environment, 5 air changes per hour occurs in the building zones. Thus, the airborne diseases are reduced and improve thermal comfort.

4. CONCLUSIONS

By incorporating, renewable energy source in a building which significantly reduces the usage of delivering energy in the building during an operation. Passive solar strategies can be utilized to reduce the energy consumption. By optimizing, the building envelope the energy efficiency is improved. The building comprises of a minimum energy efficient factor as recommended by GRIHA rating system for the regularly occupied zones. 7% of total CO_2 emissions from the building envelope relate to building materials. The cooling demand can be reduced by proper ventilation.

The building energy efficiency improves 18% in summer comfort and 13% in the winter. The baseline energy performance provides the rating method in the ASHARE standard 90.1-2007, and the building is optimized for the standard. Water conservation is also an important factor in determining the energy efficiency of the building. By generating the energy, it reduces the purchased energy from the grid. By optimizing the building to the standard, the efficiency is increased.

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