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Application of Net Zero Building Concept to Existing VPKBIET New Building by Analysing Case Studies

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ABSTRACT

This research paper explores the concept of Net Zero Energy Buildings and their applications to an existing building within the VPKBIET campus. The study involves a detailed analysis of various case studies of NZEBs to establish a foundation for retrofitting the VPKBIET new building. Energy audits, simulation models created in soft computing tools such as Autodesk's Green Building Studio, Revit, e-QUEST, and sustainable design strategies including solar panels, energy efficient HVAC systems, passive design elements and advanced insulation materials were employed to evaluate the feasibility of transitioning an existing building into NZEB. The project aims to reduce the building's energy consumption and carbon footprint, contributing to the institution's sustainability goals. However, after adopting energy efficiency measures, the building can be close to a NZEB. This paper provides the details of various energy efficiency measures and renewable energy adopted for converting an existing VPKBIET building into NZEB. The review provides technical information as well as recommendations for the transition.

I. INTRODUCTION

The NZEB concept revolves around creating buildings that generate as much energy as they consume on an annual basis. A NZEB contributes less overall use of energy with innovative design, technology integration, renewable energy sources and energy efficient management which lowers their carbon footprint and saves owners and operators money. Net zero energy buildings are gaining importance as a means of addressing the global warming crisis, growing energy demand, and lowering greenhouse gas emissions. As the global climate crisis intensifies, there is a growing need for buildings to operate sustainably and reduce their environmental impact. Net Zero Energy Buildings (NZEBs) have emerged as a solution, aiming to balance energy consumption with renewable energy production. Besides their environmental benefits, NZEBs offer considerable financial advantages by lowering operational costs and promoting long-term sustainability. Techniques such as rainwater harvesting, wind turbines, biomass heating, energy-efficient lighting, and energy storage systems are implemented to achieve net-zero energy performance. NZEBs promote sustainable development by conserving electricity and minimizing reliability on non-renewable energy sources. Therefore, the paper presents the potential transformation of VPKBIET new building into NZEB by summarizing the case studies and assessing the impact of transition on energy conservation and sustainability.

Objectives of the study:

To understand the various aspects of the Net Zero Energy concept of buildings
To identify difference between Net Zero Energy Buildings and Conventional Buildings.
To evaluate energy efficiency of existing building using soft computing tool.
To suggest techniques, methods to convert existing building to net zero building.

II. LITERATURE REVIEW

Anna Marszal (2011) suggests that the NZEB concept can be applied to the traditional buildings by adopting large renewable energy systems. The study also focuses on the importance of the energy efficient measures before adopting the renewable energy sources. Balkar Singh (2021) suggests the net zero energy balance equation for NZEB design by validating it with the case study. The paper suggests the design criteria and strategies which can be applied by both new buildings and retrofitting of existing buildings. Joshua Kneifel (2016) developed a model to predict the energy performance of the net zero energy building using Energy Plus which can be applied to other buildings considering occupancy and weather variables to enhance the efficiency. K. M. Soni (2019) reviewed India's first onsite net zero energy building. The study states that the building including the features of appropriate design, green and sustainable building materials, energy efficient equipment can reduce the energy consumption and its carbon footprint making the building a Net Zero Energy Building.

Mili Jain (2022) suggests that converting existing buildings into NZEBs require additional measures which may vary depending on the characteristics of the existing building, its location to achieve a net zero carbon status. Jayaswal (2021) studied the effects of integration of energy sources such as solar and wind power resulting in production of renewable energy on site. Saravan (2018) discussed the need to optimize water and energy usage with the importance of the building automation systems. S Deng (2014) used software tools t model and predict the performance of the NZEBs based on the design results and operational parameters. The paper suggests that converting existing buildings into NZEBs require retrofitting them with energy efficient measures, adopting renewable energy sources and incorporating energy storage systems. Wei Feng (2019) Suggested that most NZEBs using passive design and technologies such as daylighting and natural ventilation have low energy consumption intensity, some achieve net positive energy while some rely on renewable energy. Wim Zeiler (2012) suggests that ZEB have improved CO2 concentration levels improving the indoor air quality and theral comfort of the occupants.

III.METHODOLOGY

The methodology decided to achieve the objectives is shown in the figure 1.

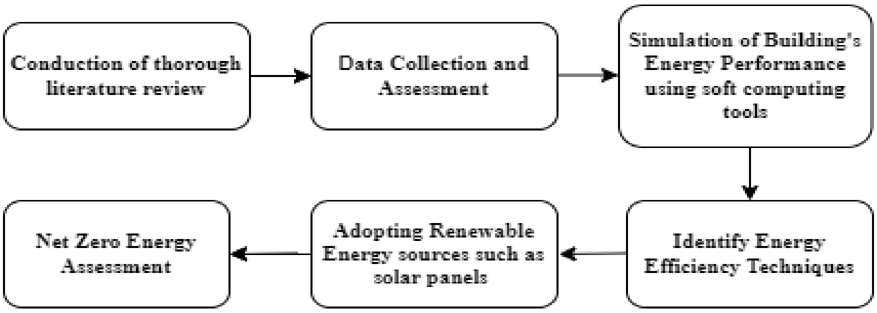


Figure 1 Methodology

IV. ANALYSIS OF CASES STUDIES

1. Indira Paryavaran Bhawan, New Delhi

Indira Paryavaran Bhawan, located in New Delhi is a LEED Platinum and GRIHA 5 Star certified building which is known for its integration of renewable energy technologies. The building was established in 2013, consuming 70% less energy than a typical structure. The building incorporates several passive design strategies such as north-south orientation, extensive landscaping, natural daylighting, and natural ventilation through the central courtyard and cross ventilation. Its building envelope features include insulation, double-glazed windows, and cool roofs to prevent heat infiltration. Materials and construction techniques include AAC blocks, fly ash-based cement and plaster, local stone floors, and composite bamboo-jute elements. Active strategies include energy-efficient lighting systems, lux level sensors, and an HVAC system utilizing chilled beams, water-cooled chillers, and geothermal heat exchange. A solar PV system with a 930 kW capacity, covering 6,000 m² with 2,844 panels, generates 1.43 million kWh annually, meeting the building's residual energy demands.

2. Akshay Urja Bhawan HAREDA, Panchkula

Akshay Urja Bhawan in Panchkula, Haryana, is the first government building constructed according to the Energy Conservation Building Codes (ECBC) and is a GRIHA 5 Star certified building. The building was established in 2012, it spans 3,900 sq.m The building has an Energy Performance Index (EPI) of 17 kWh/sq.m./yr and includes features such as passive design strategies like optimal orientation, daylighting, and ventilation. Active strategies include mechanical air conditioning and a mist cooling system. It produces excess of energy with 42.5 kW solar PV capacity which meets the annual consumption of the building.

3. Eco Commercial Building, Noida

The Eco Commercial Building (ECB) in Noida is a part of the Bayer Climate Program, which uses 70% less electricity compared to similar buildings and is energy self-sufficient. It is 891 sq.m. with an Energy Performance Index (EPI) of 72 kWh/sq.m./yr. The building's Passive design includes optimized orientation, native landscaping, daylighting, and superior ventilation. Its building envelope features include insulated walls and high-performance windows. Active strategies involve energy-efficient lighting and HVAC systems, with a 57 kW rooftop PV plant generating 100% of its energy. Excess energy produced is diverted to other buildings onsite.

4. Avasara Academy Lavale, Pune

Avasara Academy in Lavale, Maharashtra, completed in 2020, is an academic complex of 11,148 sq.m. It adopted passive design strategies like optimized site layout, bamboo screens, and articulated concrete construction for natural light and ventilation. The building features six four-story rectangular blocks arranged along hillside, maximizing views and orientation. Renewable energy sources such as photovoltaic solar panels and solar water heaters are installed on the roof providing electricity and hot water while also enhancing its sustainability.

5. Living Laboratory CEPT, Gujarat

The Living Laboratory CEPT in Ahmedabad, Gujarat, is overseen by CEPT's Centre for Advanced Research in Building Science and Energy (CARBSE). It is recognized by the Indo-Swiss Building Energy Efficiency Project (BEEP), it utilizes passive design strategies like optimal orientation, landscaping, and daylighting, alongside active measures such as energy-efficient lighting and a chilled beam system. It has 50% roof coverage of PV panels, the panels generates 70 kWh/m2/yr, contributing to its energy self-sufficiency.

6. Malankara Tea Plantation

The Heritage Building Complex at Malankara Tea Plantation in Kottayam, Kerala, is the nation's first Net Zero Energy office complex, with 27 KW solar power plant. It is grid independent, reducing carbon emissions by up to 47 tons annually and diesel fuel usage by approximately 97%. With a payback period of less than five years, it has potentially became an energy-plus building by selling excess electricity back to the grid.

7. Sun carrier Omega Building

The Sun Carrier Omega Building in Bhopal, India, of 9888 square feet is a private office. It is LEED Platinum certified. It's recognized for its advanced renewable energy solutions, including the Sun Tracking Intelligent Solar PV System. Energy efficiency strategies involve meeting 100% of the building's energy needs through onsite renewable energy generation and storage, alongside initiatives such as high albedo paint and efficient lighting. The building promotes sustainability through features like onsite renewable energy generation, water efficiency measures, and resource management practices. Additionally, it prioritizes indoor air quality and occupant health with low-emitting materials.

8. PL-13 Annexe Building Godrej & Boyce Mfg. Co. Ltd

The PL-13 Annexe Building by Godrej & Boyce in Mumbai is of 24,443 square meters and is the India's first "Net Zero Energy Rated" project by the IGBC. It has passive design strategies like landscaping and daylighting, along active measures such as optimized HVAC systems and energy-efficient lighting. It include a 120 kWp rooftop solar PV system, contributing 8% to its energy needs, and has adopted an automated cleaning system to further enhance efficiency and water savings.

4.1. ENERGY PERFORMANCE OF VPKBIET NEW BUILDING

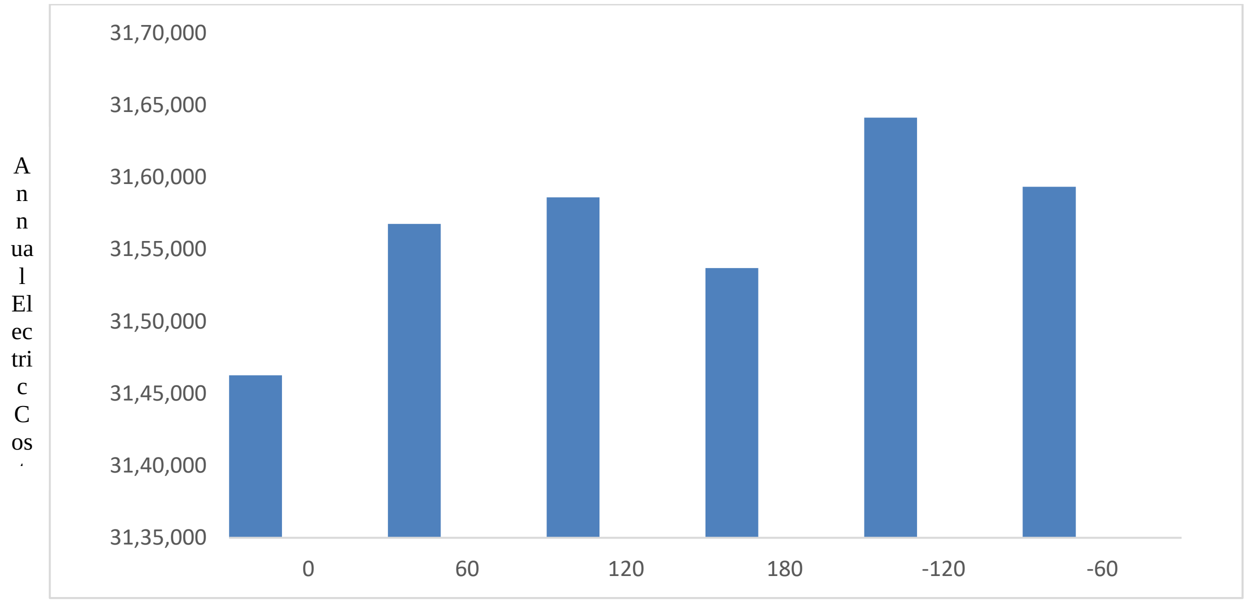
To achieve an energy efficient building in VPKBIET campus, software like Green Building Studio by AutoDesk, Revit and E- Quest were used.

4.1.1 AutoDesk Green Building Studio

Models for each floor of the building were made in the Revit for further analysis in the Green Building Studio. These models were close to accurate in dimensions to the actual building with respect to the 2D floor plans of the New Building in VPKBIET Campus. The exported .gbXML files were then imported into the GBS software for the analysis and with the already known input data we received the approximate results for the building floor-wise. The software can present a 15-20% of inaccuracy in the analysis according to the mentor for this method with respect to his findings for his own projects. The following data was achieved after the analysis (cost in rupees):

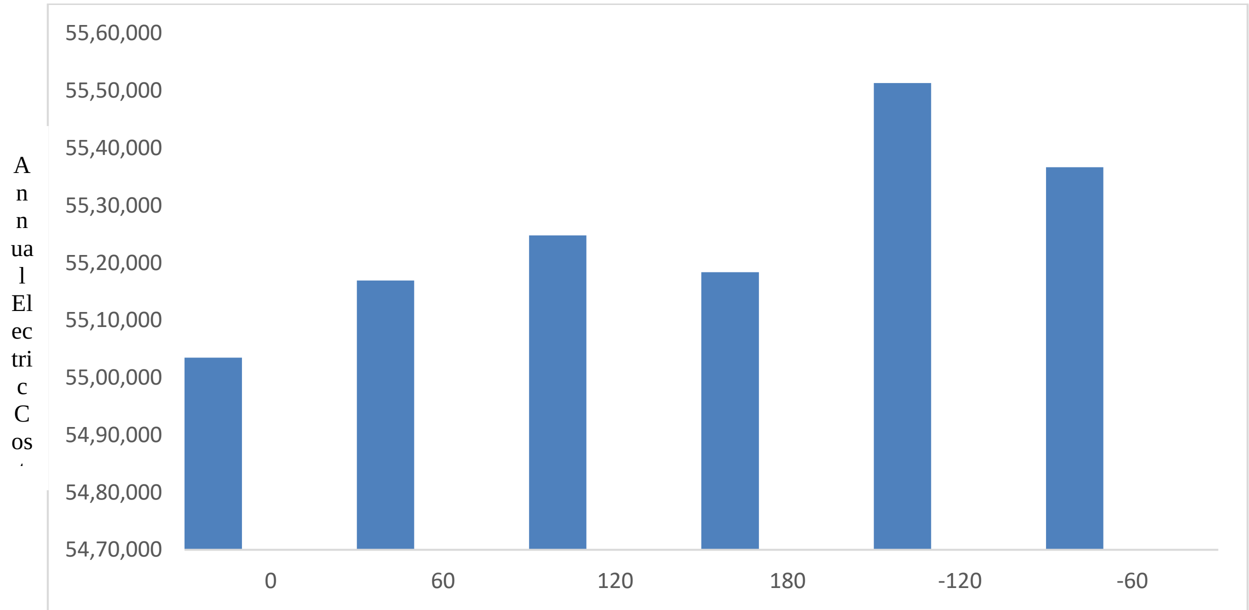
Table 1: Energy & Cost analysis of New Building.

Floor	Floor Area (m^2)	Annual Electric Cost
Lower Ground Floor	1,351.61	31,46,263
Ground Floor	2,468.19	55,03,489
First Floor	2,429.03	54,80,847
Second Floor	853.022	2069116



Rotation in Degree (˚)

Fig. 2: Energy Consumption of Lower Ground Floor with respect to rotation from its original axis.



Rotation in Degree (˚)

Fig. 3: Energy Consumption of Ground Floor with respect to rotation from its original axis.

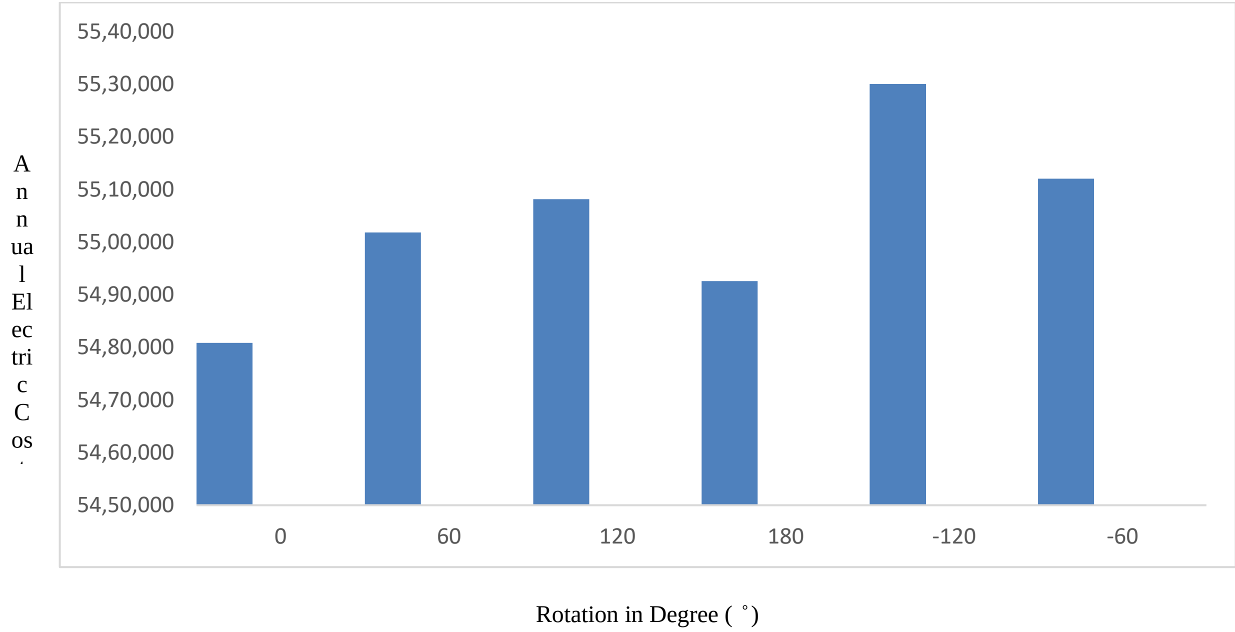


Fig. 4: Energy Consumption of First Floor with respect to rotation from its original axis.

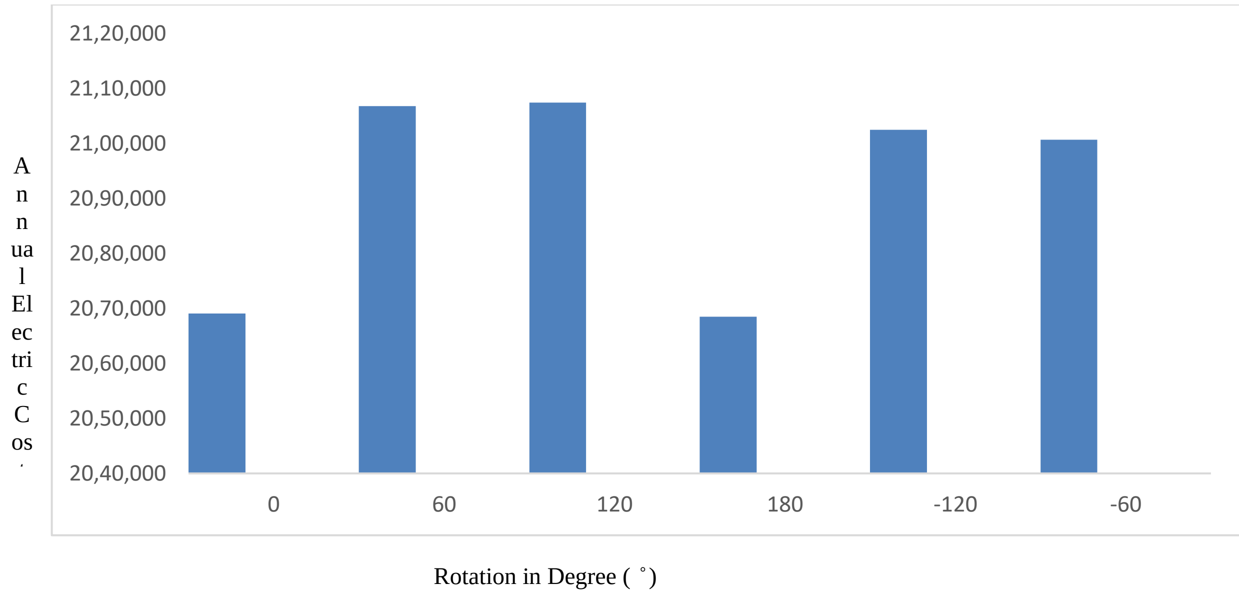


Fig. 5: Energy Consumption of Second Floor with respect to rotation from its original axis.

4.1.2 E-Quest

Various models of VPKBIET, New Building were made by importing the CAD file of the New Building. Model 1 shows the standard building made without adopting any Energy Efficiency measures. Model 2 to 12 shows the building after adopting the energy efficiency measures including changing the U values of walls, roofs, and windows, providing insulating materials and HVAC systems.

The CAD plan was imported in the software in .dxf format. The plan was zoned in different parts. The weathering file of the nearest city Pune was imported for considering the weather conditions. The building envelope details, standard window shading coefficient and according to the previous year audit and observation of the internal loads (lighting, equipment) were provided to the software. For Model 1 no energy efficiency measures were adopted. For Model 2 to 12 energy efficiency measures including HVAC system and changing U values of the building envelope were adopted.

U value: The rate at which heat moves through a structure is called thermal transmittance, or U value. The U value of a structure decreases with increasing insulation. Lower the U value, the lower is the heat flow which results in greater energy savings and pleasant and constant room temperature.

Therefore, materials with lower U values should be adopted. Lower U values can be obtained by using the insulating materials such as

1. Polystyrene materials
2. Spray Foam Insulation
3. Cellulose Insulation
4. Fiberglass Insulation
5. Mineral Wool Insulation
6. Polyisocyanurate (Polyiso) Insulation

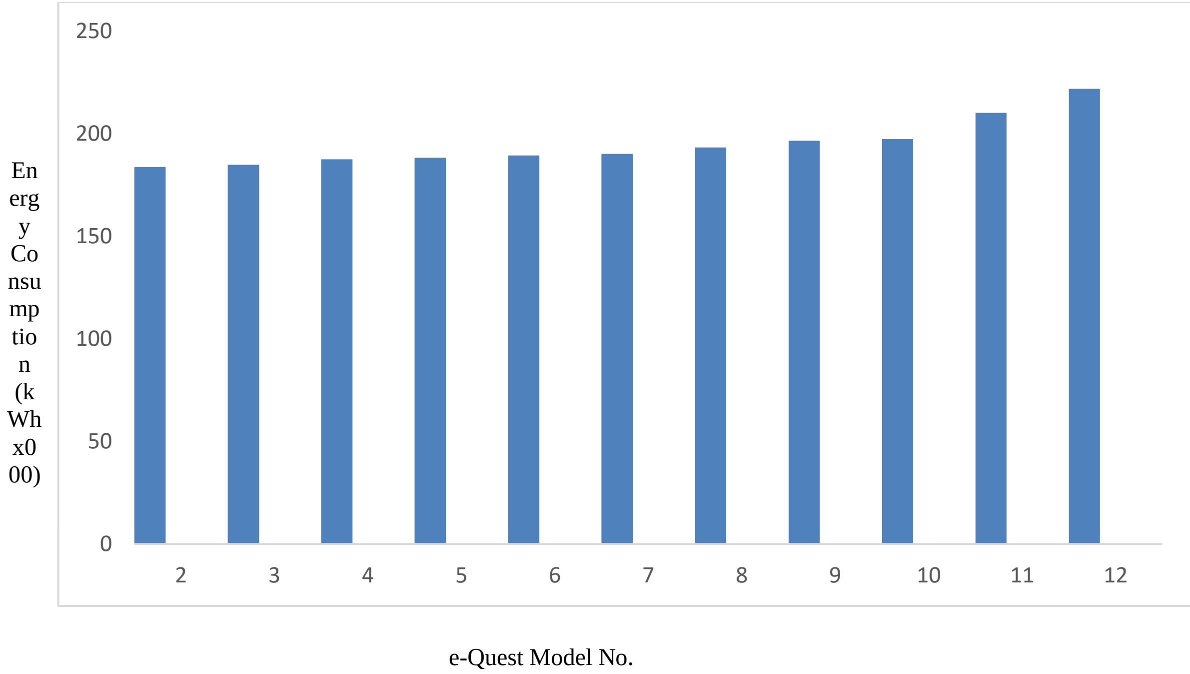


Fig. 6: Results of the models

According to the results, Total annual energy demand of the building if the lowest U values and HVAC system are adopted is 183830 kwh in which miscellaneous equipment consumes 55.27%, area lights consume 22.28%, Pumps and Aux consumes 19.6% and Vent Pipes consumes 2.81% of the total energy demand.

And if highest U values and HVAC system are adopted, the total annual energy demand is 221910 kwh in which miscellaneous equipment consumes 45.79 %, area lights consume 18.45 %, Pumps and Aux consumes 31.12 % and Vent Pipes consumes 4.64 % of total energy demand.

4.2. CALCULATION OF COOLING LOADS FOR HVAC SYSTEMS

For a HVAC system to design is a lengthy task. Cooling loads for a building must be known for the further design process of an HVAC system in a building. In this project, the approximate cooling loads are calculated for any future references. These cooling loads are calculated using the E-20 Excel Sheet for calculations of heating and cooling loads.

The total Tons of Refrigeration required for the whole building is **379.86 TR**. The total cooling load for the building are said to be **1336 kW/hr** approximately.

The following table shows the data floor-wise, and the detailed data is presented further:

Table 2: Cooling loads for Main Building

Floor Description (Total Room Area)	Tons of Refrigeration (TR)	Cooling loads (kW/h)	Percentage (%)
Lower Ground Floor (1324.48 sq.m.)	69.37	243.98	18.262
Ground Floor (2081.73 sq.m.)	135.72	477.33	35.723
First Floor (2140.83 sq.m.)	124.86	439.15	32.873
Second Floor (733.25 sq.m.)	49.91	175.54	13.142

4.3. CALCULATIONS FOR SOLAR ENERGY REQUIREMENT

Number of solar panels required

Energy consumption per month = 24,165Kwh

Peak hours – 4

∴ 201.375 kw system is required.

No. of panels required to satisfy the complete energy need for the building = 201.375 / 0.32

=629.29 = 630.

Available panels = 211

Solar panels tilt angle = Latitude x 0.87 + 3.1 ≈ 18.153 x 0.87+3.1 =18.9 degree from horizontal facing true south.

Area of Solar panels =

Length (L) = 1.98 meters

Width (W) = 1.05 meters

Tilt angle = 18.9 degrees

Standard Ground Area = 2.079 m^2

Projected Area = 2.079 / cos (18.9) ≈ 2.19 m^2

So, the area of the ground required for one solar panel installed at tilt of 18.9 degrees is approximately 2.19 m^2.

The terrace area with no solar panels is shown in the fig. 53.

Terrace area of the VPKBIET Building according to the CAD plan = 631.92 m^2

Area of 50 solar panels = 50 x 2.19 = 109.5 m^2

According to the area calculated above, minimum 50 solar panels can be suggested to be installed at the terrace.

Total energy generated by the 211 solar panels-

No. of the solar panels installed = 211

No. of solar panels suggested = 50

Power of each solar panel = 320 Watt.

∴ 320 x 261 = 83520 Watt

= 83.52 Kw

1 kw of solar panels generate 4 kwh of electricity in a day.

∴ 1kw = 4 Kwh ∴ 83.52 x 4 = 334.08 Kwh

Solar panels of 83.52 Kw generate 334.08 kwh of electricity in a day.

Solar panels generate 10022.4 kwh of electricity in a month.

Solar energy generation is 120268.8 kwh units after installing 50 more solar panels.

V. COST ANALYSIS FOR INSTALLATION OF SOLAR SYSTEM

This thumb rule was derived from IIT Bombay Energy Literacy Training

1 : 1 : 10 : 1000

Where, following represents

1 – Electricity Consumption

1 – Rooftop Area, Battery Requirements

10 – Solar panel Requirements

1000 – Cost Requirements

Here, 1 unit/ month electricity consumption = 1 sq. feet area requirement

1 unit/ day electricity consumption = 1 kwh battery requirement

1 unit/ month electricity consumption = 1 x 10 = 10-Watt solar panel requirement

1 unit/month electricity consumption = 1 x 1000 = Rs. 1000 cost requirement

Using Thumb Rule,

Most efficient model identified by e-Quest software and its cost for additional solar system.

Electricity Consumption = 183830 kwh annually = 15320 kwh per month

= 510 kwh per day

If the monthly requirement is 15320 kwh,

∴ Rooftop space requirement = 15320 square feet

Battery requirement = 510 kwh

Solar panel requirement = 15320 x 10 = 153200 Watt

Money requirement = 15320 x 1000 = Rs. 1,53,20,000 /-

VI. RESULTS AND DISCUSSION

After adopting energy efficiency measures like HVAC systems, providing the insulating materials as well as addition of the solar panels, the building can be close to a Net Zero Energy Building. The initial investment, which is required for installing insulation, HVAC system, including ductwork, equipment and labour costs is expensive. With the age and condition of the New Building, retrofitting for HVAC compatibility could further increase the expenses. The building's existing infrastructure can pose challenges for installing HVAC system effectively including structural limitations. Retrofitting insulation requires alterations to the building's structure which may compromise the integrity of the new building if not executed carefully. Installing insulation may alter the appearance of the building's interior and exterior. Increasing the number of solar panels to 261 enhance the building's capacity to generate more renewable energy, reducing the reliance on grid supplied electricity. The additional 50 solar panels can lead to cost savings on electricity bills.

VII. CONCLUSION

The technologies and various measures applied by the case studies, while their planning, designing, and construction, it is suggested that relying on renewable energy sources alone will not make the building NZEB. Providing adequate lighting design, adopting various technologies such as HVAC systems, renewable sources and changing the buildings material properties can reduce the energy load and fulfil the demand of energy of the building. After analysing the literatures and case studies, the results produced from software the various techniques and measures suggested are HVAC system, insulating materials to the building shell, changing the shading coefficient of the windows and renewable energy alternatives.

Therefore, addition of 50 Polycrystalline Solar panels is suggested along with other energy efficiency measures to make the VPKBIET, New Building close to the Net Zero Energy Building. Results obtained after considering the suggested measures, the reduction of energy consumption is almost 27.50%. The VPKBIET New building can be converted to NZEB with maximum 69.9% after adopting suggestive measures.

Providing wind turbines would not be a feasible option but by installation of vertical tower on the terrace at a design height, the advantage of wind energy can be taken for the generation of electricity.

The initial investment in providing energy efficiency measures may be challenges, the numerous benefits they provide in terms of energy savings, environmental impact, property value and long-term sustainability make it a rational decision.

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