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Modelling, Designing and Optimization of Net Zero Energy Building

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Abstract: With a value of around 40% of overall energy consumption, buildings are a significant main energy user in the global energy sector. Currently, the absence of conventional energy sources encourages the construction of net zero energy buildings (NZEBs). Net or nearly zero energy buildings (NZEB) are exceptionally energy-efficient structures with very little demand for energy, all of which are supplied by renewable resources. Such structures annually balance their energy use and production. It's crucial to understand the broad notion of net zero energy construction. The paper's objective is to present and discuss various strategies and ideas to achieve Net Zero Building through actual Modeling. Designing and Optimization of Building
Keywords: NZEB, Smart-Grid, EPI, Optimization, IOT.

I. INTRODUCTION

Are you conscious of the potential environmental impact of your workplace or residential structure? Is it conceivable that you are unaware of dangerous chemicals being released by your building? We are fully aware of the different environmental problems, such as air, water, and global warming pollution, as well as the precautions that must be taken to avoid them. In India, if we adopt sustainable architecture and green construction practices, we may not only protect the environment but also lower our total ownership expenses. The second-largest producer of demolition trash and greenhouse emissions is the building construction sector (35-40%). Building construction and afterwards lighting or air-conditioning systems use the majority of the energy. While different amenities like lighting, air conditioning, and water heating make buildings' occupants more comfortable, they also use a tremendous amount of energy and contribute to pollution. Additionally, tenant activities produce a significant amount of solid and liquid waste Little more efficiency is not the goal of green construction involves designing buildings that make the best use of local resources and the environment, and importantly are constructed to consume less water, and other materials According to TERI esteem India could save more than 8,400 megawatts of en or enough to light 550,000 houses annually, in structures in Indian urban areas were compelled to adhere to green construction principles.

II. OBJECTIVE

To Design and Optimize the Conventional Single-Family Housing to Net Zero Energy Building

III. LITERATURE REVIEW

According to Reshmi Banerjee, the Net Zero Energy Building (ZEB) does not increase greenhouse gas emissions. Given current building technologies and design strategies, he observed that a growing number of buildings are meeting this standard, increasing confidence that a ZNE goal is feasible. In the interaction between buildings and grids, the Net ZEBS become an active part of the renewable energy infrastructure.[1].

Masa Noguchi and colleagues created the Eco-Terra house prototype, which was created to be energy-efficient to avoid adverse environmental effects. According to the investigation, the house almost eliminates its energy use, and it offers its residents a comfortable and healthful indoor atmosphere.[2]. This building sector consists of large, small, commercial, and public structures. The majority of the electrical equipment in these buildings is standard, including lights, fans, coolers, heaters, and consumer gadgets. The rapid increase in residential building energy use in recent years presents a challenge for zero energy residential building (ZERB) technologies, which seek to significantly lower residential building energy use Unfortunately, the majority of the buildings are run inefficiently about energy use Buildings have 40-50% potential for energy efficiency gains [3] With a proportion of between 30% and 40%, buildings are one of the biggest consumers of electrical energy worldwide[4] According to data released by the Ministry of Statistics and Programme Implementation, the Government of India, per capita energy consumption increased by about five times between 1980 and 2010 [5]

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IV. METHODOLOGY

Our design focuses on minimizing the ecological impact a structure has on the land it is constructed on. The net-zero performance per performed relative planning and fusing conventional wisdom and current technology. The following are the primary design elements used in

our project: By using balconies to create buffers, we may achieve comfort with natural ventilation and supported natural ventilation, while also taking into mind the micro-environmental characteristics of the site location and the user experience. The humidity is consistently high due to the seaside location. By simulating the microclimate and including dehumidifiers in our system, we can validate the extent to which our ventilation tactics contribute to the comfort

•Adopting passive design principles, such as using local materials, minimizing the use of concrete, orienting the plan in y the direction of the wind and sun, collecting rainwater, using energy-efficient appliances, etc.

Site Details

Site Area- 1740 m2

• Permissible Built-up Area 3480 m2 (for 10 row
houses).

• Proposed Estimated Built-up Area 240 m2 (for the 1-row house)

Figure 1 Site Plan

Energy Performance Index:

EPI Goal: 15 kWh/m2 per year.

The preliminary estimate of on-site renewable energy generation potential

•Wind Energy Generation potential = 5000 kWh per year

•Solar PV Potential = 13200 kWh per year per house.

• An 8.8kW plant is feasible per house. For the
domestic wind turbine, a wind speed of 6 m/s for a rotor diameter of 7 m is considered.

A. Performance Specifications

1) *Climate Zone:* Navi Mumbai is located in a hot, humid region. The location is particularly close to two lakes, a strait, and mangrove woods. Both the artificial lake Vashi Gaon Chowpatty and the holding lake Vashi are located around 400 meters apart from the site. Less than a kilometre separates the location from a strait. Additionally, a substantial mangrove cover surrounds these water features. The microclimate has effects, as determined by user experiences.
2) *Site Analysis:* Vashi is a node in Navi Mumbai, Maharashtra, across the Thane Creek of the Arabian Sea on the outskirts of Mumbai. The site is plot number 14 of sector 10, Vashi It has good connectivity to other nodes of Navi Mumbai and Mumbai through local trains, buses, and auto-rickshaws with tar approach roads and cement gravel roads. The terrain is flat, with rock formation derived from Deccan Basalt and granites, gneisses, and laterite. The soil is calcareous, neutral to alkaline in reaction (pH 7.5 to 8.5), and clayey, with high water holding capacity (200-250 mm/m) The site is in an urban setting. The approach is from the connecting road. The main road is 150 m from the site. The nearest bus stop is also 150 m from the local railway station, 2.5 km from the site. There are hospitals and schools in a 1-kilometre radius. The location of the site is prime in the sense of approachability, with hospialshospitalshonearby and bus and ra way stops in close vicinity. The project caters to the redevelopment of the site. However, the new construction is also to cater to the ten families only. No expansion is planned. So, we know the end-users that the project caters to.

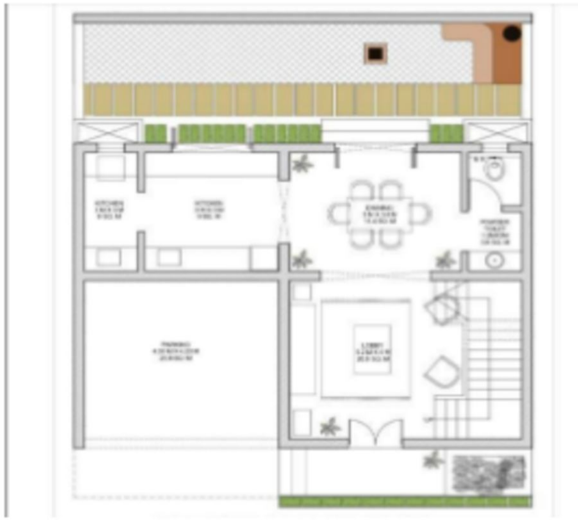

Figure 2: Ground Floor Plan

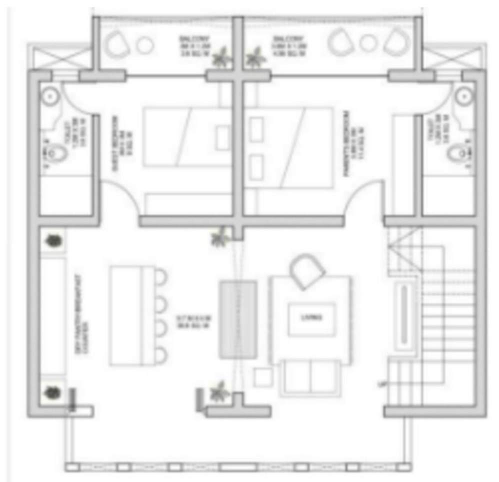

Figure 3: First Floor Plan

Figure 4: Second Floor Plan

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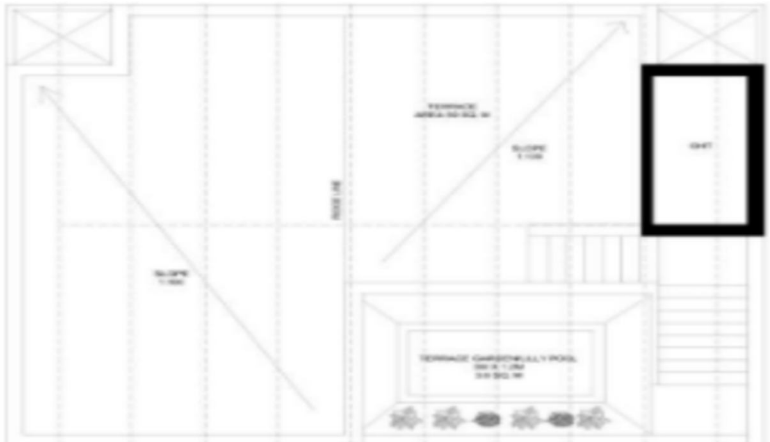

Figure 5: Terrace Plan

B. Performance Specification.

Building Envelope		
Wall External	(0.6SRI Paint Agrocrete(200)+ Air Cavity(25)+Rockwoo1(50)+Plaster (10))	U=1.22 6
Roof	Insulated Roof (0.3SRI China Mosaic(25)+PCC Screed(50)+PUFF Insulation-Vapour Barrier-WaterPro-of Hollow Core (100)+ Plaster(10)	
Window	Double Glazing Dbl Clr 6mm air gap 13mm	Vlt=0.781 U=2.665 Shgc=0.703
HVAC		
Type	VRF Dehumidifier and Air Conditioning System	
Model	Company: Daiken VRV VI Model-: VRV RXYTQSUTYF Tonnage: 5.4 Power 380-415V/50Hz	
Renewable Energy		
Type	Roof Mounted Solar PVs Power = 8KW Efficiency = 18%	

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1) Energy Performance

Navi Mumbai, formerly known as New Bombay, is a planned community located in the Konkan region of the Indian state of Maharashtra. The climate in Navi Mumbai is tropical. The amount of rainfall is substantially lower in the winter than it is in the summer. The average annual temperature in Navi Mumbai is 26.6 °C or 79.9 °F. The average annual rainfall is about 1915 mm (75.4 inches). When it comes to relative humidity, July tops the list (88.90 per cent). The month with the lowest relative humidity is December (56.23 per cent). The biggest number of rainy days occur in July (29.00 days). The month with the fewest rainy days is March (0.17 days).

2) Reduction Loads

a) Building Form: In sites with constrained plots in places like Navi Mumbai, it is crucial to analyze the site and the climate early in the design process because space limitations may result in form restrictions. Our main goal was to improve natural ventilation, thus we tried to design an open zig-zag orientation with more open facades. Even though these architectural forms were appealing, they resulted in a smaller amount of ground coverage and forced us to raise the home higher. After weighing the benefits and drawbacks, we chose design iterations with more ground surface covered, fewer stories, and more effective site usage.

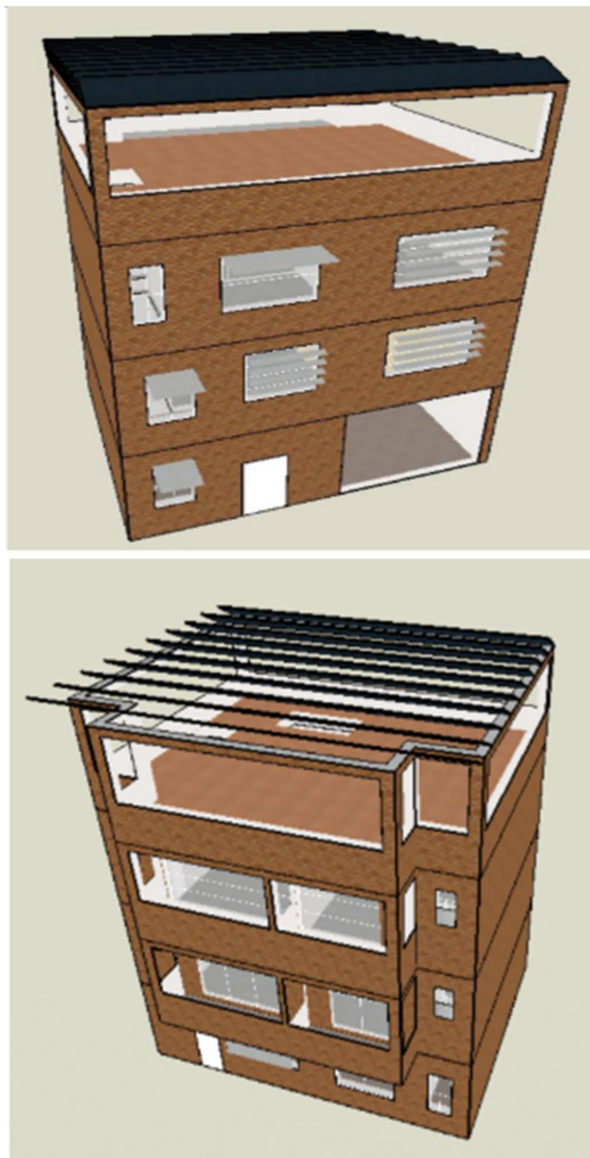

Figure 6: Design Builder Model

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3) Design Envelope

Despite being a necessary component of construction, concrete is bad for the environment. To provide the occupants with an organic living environment, we intended to employ materials that adhered to this principle. To avoid adding to the concrete jungle, we chose to use carbon-negative building materials. The Agrocrete material we have chosen offers greater thermal performance in addition to being carbon negative. We do away with the necessity for additional insulation by combining Laurie Baker's rat trap bond-building method. All four of the bedrooms have balconies, and the living room has a jail wall with most windows having single or double glass.

Figure 7:Laurie Baker's rat trap bond

C. *Integration Of Low-Energy Comfort Systems*

A desiccant is a material that collects water molecules from the air and dehumidifies it. It can be solid or liquid. The desiccant is heated to release the moisture it had been holding onto after being initially employed to capture moisture from the air. Desiccant systems are powered by a continuous process called the phase change cycle. In place of the more traditional vapour compression and absorption cooling systems, desiccant cooling systems are heat-driven cooling apparatuses. A desiccant cooling system works by dehumidifying the air inside a rotating dehumidifier, or desiccant wheel. The resulting dry air is then further cooled by an evaporative cooler after being partially cooled in a sensible heat exchanger (rotary regenerator). It then blows the generated cool air into space. The system can be run in the ventilation or recirculation modes in either an open cycle or, more frequently, a closed cycle.

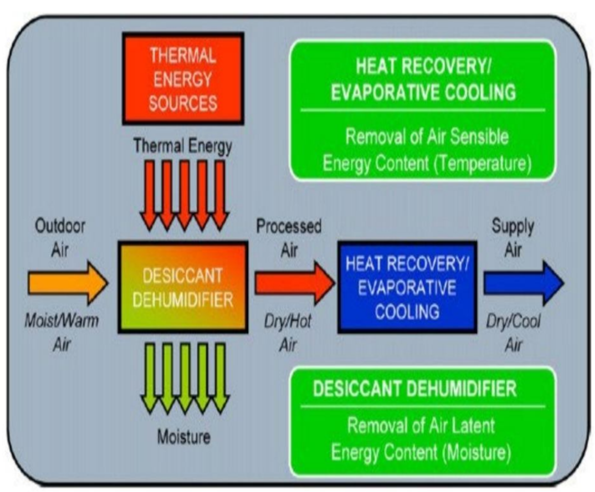

Figure 8:Function Of Dehumidifier

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Advantages: Highest low dew point supply air CMH/kW of regeneration: High-Performance Efficiency and Energy Efficient Desiccant cooling systems don't include any harmful materials, unlike traditional vapour compression freezers. As a result, they might be regarded as eco-friendly air conditioning technology. Unit Construction: robust, durable, > 20 years life

D. Sufficient Renewable Energy Generation With Smart Grid Capabilities

The infrastructure and electrical energy system need to be modernized to provide a more intelligent and dependable electricity grid, and this is where a smart grid comes in. When compared to traditional grids, smart grids provide various advantages. Smart grids enhance the grid system's physical and financial operations, boosting dependability and sustainability.

1) Lighting Optimization

We have planned the spaces with daylighting as a fundamental design technique to achieve our goal of giving the users an organic experience. However, because we are using natural ventilation as our main design technique, it is crucial to apply the right shade and strike a balance between daylight and glare to prevent closing the windows. We designed our apertures using daylighting simulations with an illuminance range of 130 to 1300 lux to achieve a balance between natural light and glare. The daylight simulation outcomes for cloudy weather are displayed in the following photos.

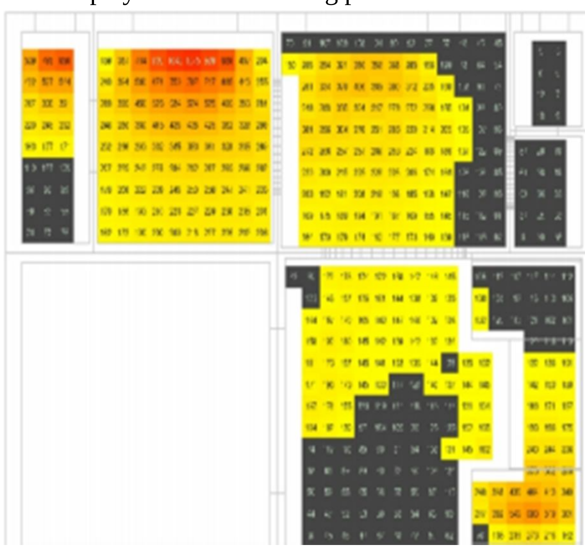

Figure 9: Ground Floor Illuminance

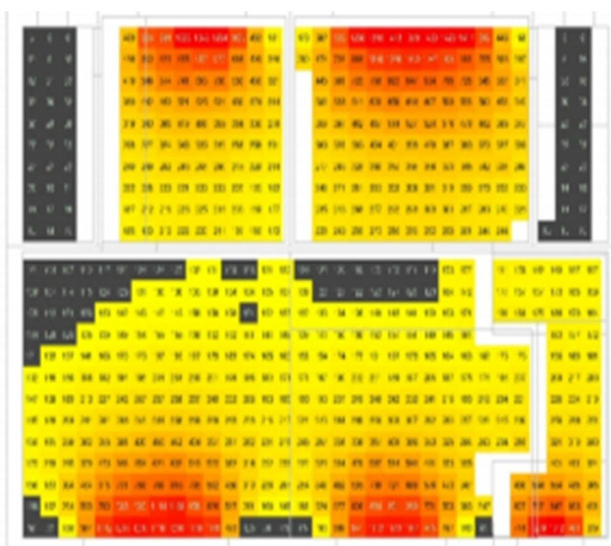

Figure 10: First Floor Illuminance

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2) Energy Analysis

In the course of a building's life, the HVAC system uses the most electricity. We intend to use natural ventilation as our main design method while taking the micro-environmental factors, the comfort band, user experience, and our design philosophy into consideration. First, we were able to choose a plan that aided natural ventilation by utilizing the westerly breezes thanks to climatic study. To help with ventilation, we then planned low-energy, high-performance BLDC fans. We may install more assisted ventilation ducts in later iterations to improve comfort, particularly in the hotter months of April and May. In coastal areas like Mumbai, latent loads make up the majority of the cooling load. Additionally, the microclimate makes the area cooler but also makes it more humid. It is ineffective to achieve comfort by using an air conditioner to reduce latent loads. To handle the latent loads, we, therefore tried to find more simple alternatives. Temperature and specific humidity changes at critical state points of a solar-assisted solid desiccant cooling system are examined for the ventilation and recirculation modes using TRNSYS simulation software. It looks that the COP in the recirculation mode is a little bit higher than it is in the recirculation mode. Additionally, in the recirculation mode, the regeneration temperature needed for dehumidifier desorption is reduced. Additionally, in the recirculation mode, the regeneration temperature needed for dehumidifier desorption is reduced. The recirculation cycle looks to be superior and more effective than the ventilation mode due to the lower thermal energy needed for reactivation and, as a result, higher COP.

3) Affordability

Construction cost optimization and total cost reduction were two of the team's primary goals when planning the project's layout. The team take several simple yet effective steps to achieve these objectives. 1. We intend to use environmentally friendly Agrocrete® bricks, which are made from crop byproducts and industry byproducts. Similar to Red and Fly Ash Bricks, Agrocrete® can be used in load-bearing and non-load-bearing applications. A Red Brick is almost 5 times the size of an Agrocrete® Solid Block, which lowers construction costs by 30% and enables quicker and simpler masonry. Additionally, Agrocrete® has a lower thermal conductivity, which results in lower running costs for the occupants of the structure. The accompanying image provides a summary of the differences between Agrocrete® bricks and traditional red bricks.

Parameter	Red Bricks	Agrocrete® Solid Block
Strength	7 MPa	5 - 7.5 MPa
Density	1800 - 2000 kg/m^3	1200 - 1500 kg/m^3
Water Absorption	18-20%	10 - 20%
Durability	75+ yrs.	75+ yrs.
Thermal Conductivity*	0.8 W/mK	0.4 W/mK
Embodied Carbon	0.24 kgCO_2/kg	–0.2kgCO_2/kg
Size of Brick (in mm)	215 x 102.5 x 65	400 x 150 x 130
Cost of Walling per sq.m. (incl. masonry, plastering & mortar joints)	₹ 2245	₹ 1255

Figure 11: Comparison Between Red Brick and Agrocrete Solid Block

Using Agrocrete® bricks instead of traditional ones can cut the cost of building per square meter by over 50%. Nothing is more opulent than a floor made of beautiful granite or marble. However, the elegance and beauty of granite come at a high cost to the economy and the environment. Granite stone flooring typically costs between Rs. 90 and 100 per square foot. but the kota flooring costs only Rs. 60 per square foot. A fine-grained, robust, firm, and uniform natural stone is the ko stone. Shiny kota stones look as good as floors made of marble or granite. Furthermore, shaded kota stone constantly maintains a cool temperature, aiding in the regulation of the temperature within. The cost of raw materials utilized in construction is significant. Therefore, cutting back on the quantity and price of raw materials utilized can be the best strategy to minimize the entire cost of building. Additionally, if we can accomplish several benefits (such as thermal insulation of the structure while reducing overall cost and raw materials), it will be a double benefit as a sustainable design. Famous architect Laurie Baker developed the double-wall Rat trap Bond (also known as the Jail Wall design) in Kerala in the 1970s. It is a double-wall technology that significantly reduces construction costs, reduces material and mortar consumption, and helps to increase thermal efficiency without compromising wall strength. In Rat-Trap masonry, rather than having the usual horizontal alignment, bricks (standard size 230 X 110 X 75 mm) are positioned vertically so that the 110 mm face is visible from the front elevation. However, because the wall's breadth (230mm) does not change, the 75mm face is replaced by an interior emptiness. This technique saves roughly 30% of the brick and mortar material, bringing down the cost of the complete construction to about Rs. 300-350/sq.ft.

On average, our operational energy requirements are roughly 40% accounted for by HVAC. One of any building's biggest energy consumers is air conditioning equipment. Our team focused on natural ventilation and assisted natural ventilation employing fans (to get increased air velocities and ACU) and dehumidifiers to prevent mechanical cooling systems .in the buildings to reduce energy consumption and ultimately reduce the effective cost (to counter the mainly latent loads). The plan attempts to do away with the requirement for mechanical cooling. This will undoubtedly help lower operational and maintenance expenses significantly over time.

a) *Home Automation and Building Management System:* As the average resident strength is just 5 persons, with a range of 2–6 people, we have a low population density. Therefore, there is a lot of potential for cost savings with home automation. Facility managers now have access to data that was previously out of their reach thanks to IoT. To improve operational sustainability, these tiny networked sensors can be employed in conjunction with automated building systems. For instance, IoT sensors may dynamically adjust the proper ventilation and lighting levels inside the structure based on temperature, weather, and CO2 data. It is not necessary for the facility manager to manually keep track of these changes or enter data from numerous machines. The following design iterations will focus on the system specs.
b) *Agrocrete:* Our team worked to avoid using concrete in the building to make it sustainable and environmentally friendly. We discovered a business called GreenJams, whose mission is to offer clients products and services that help them to lead climate-positive lifestyles. They provide the ideal answer for carbon-negative and less expensive building materials. A "First its type" construction material, Agrocrete by Green Jams is created from crop by-products and industrial waste. In substitution of clay bricks, fly-ash bricks, and concrete masonry units, Agrocrete solid blocks are ideal. They are 25% more energy efficient and roughly 50% less expensive than traditional bricks. Additionally, they are tough and require 20% less plaster than standard clay bricks while providing 50% more thermal insulation

V. CONCLUSION

The zero energy idea helps to preserve the environment while reducing global warming. The zero energy building, our final year project, stands out for being entirely constructed with sustainability and green building in mind. The building was designed with a "green" philosophy in mind, showing the most advanced HVAC technology combined with recyclable materials. Additionally, it's important to use the right energy conversion tools to maximize the use of water, chilled and hot water, STP, and solar energy conversion. The aforementioned characteristics will be optimized with the aid of the building automation system. The purpose of the prana building is to show that it is possible to design a zero-energy structure and that it is useful for energy conservation.

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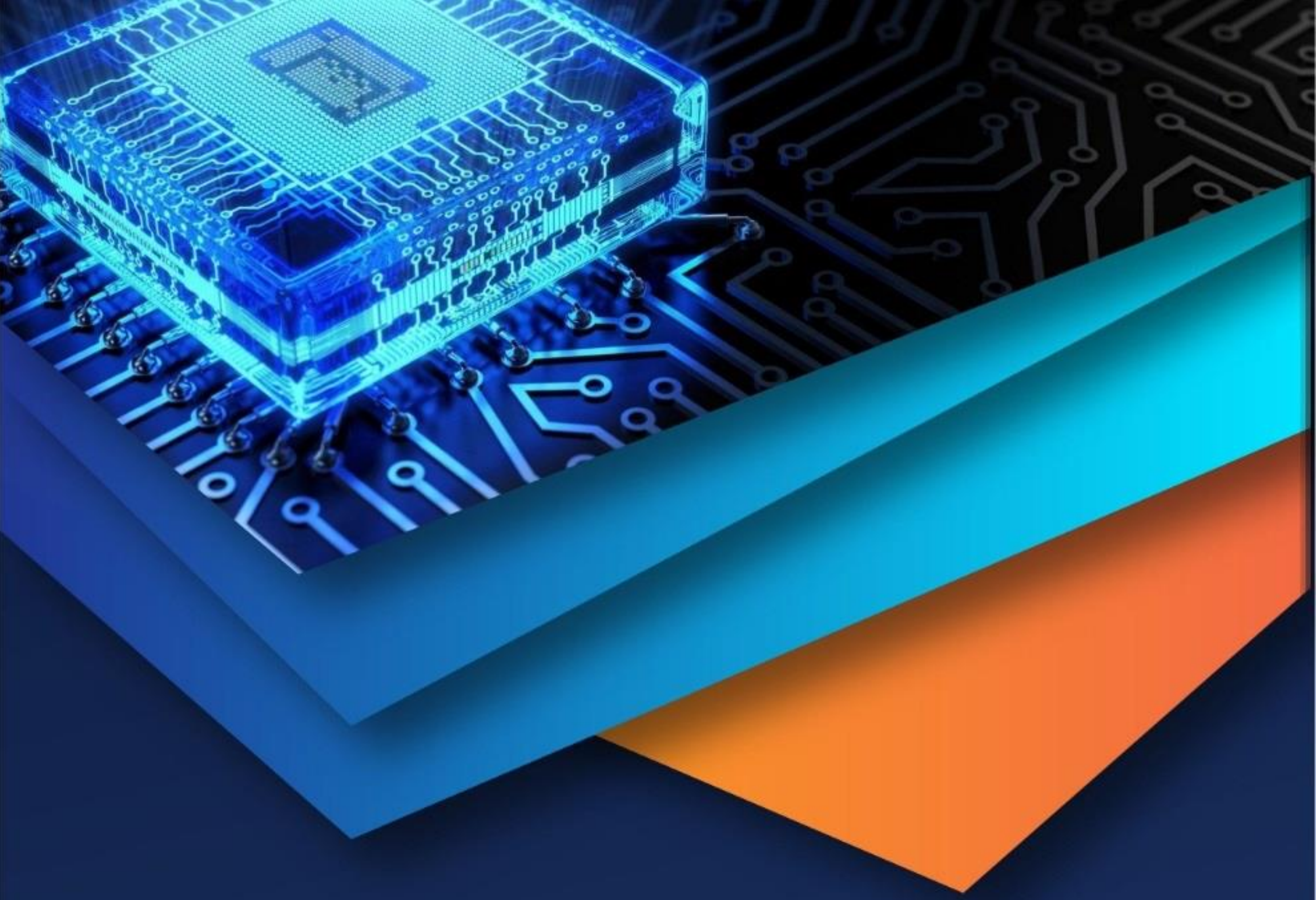

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