# Planning and Designing of Net Zero Energy Educational Building


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DEPARTMENT OF CIVIL ENGINEERING

CECOS University of IT and Emerging Sciences Hayatabad Peshawar


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B.Sc. Civil Engineering


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# ABSTRACT

At the turn of the twenty-first century, the world's energy situation has drastically changed. As consumption has increased, pollution from the environment has worsened, causing both global warming and ozone layer depletion. The importance of interior spaces from a human comfort and health perspective is rising. Buildings are thought to be the primary cause of about 50% of the world's energy demand. Thus, a change in the world's situation, the environment, and energy use was required, which is how the idea of a net zero energy building came about. A building that uses no net energy is referred to as a net zero-energy building (NZEB). In comparison to a comparable ordinary conventional structure, this one consumes less water, maximises energy efficiency, protects natural resources, produces less trash, and offers healthier areas for residents. By choosing a location in Phase 5 Hayatabad, Peshawar, we hope to demonstrate the significance and mounting necessity of implementing "sustainable development" techniques. SketchUp Pro 2020 software was used to model the structure's design, while Lumion 10 software was used to create 3D renders of the design. The conventional appliances have been replaced by state of the art components. The use of industrial sludge in construction materials is being pursued as a novel idea in addition to design. This is advantageous in that, when implemented on a wide scale, it reduces waste generation and conserves the finite natural resources that are utilised by numerous sectors. To evaluate the effects and modifications the net zero energy building has on the environment, an environmental audit was also carried out. Three main outcomes are provided by the audit: energy savings, water savings, and building material savings. This study's goal is to provide the groundwork for future zero-energy buildings throughout the nation. This study is unique and significant since it makes suggestions for changes to the way the structure is oriented and recommends changes to the appliances used and the materials used as well as their execution and visualisation.

Keywords: NZEB, Industrial Sludge, Environmental Audit, Energy Efficiency

# UNDERTAKING

We certify that research work titled "*planning and designing of net zero energy educational building*" is our work. The work has not been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged/referred.

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# Introduction

## 1.1 Global scenario

Concern over the rise in energy use and its negative consequences on the environment is rising. Even a half-degree Celsius increase in global temperature puts our food supply, health, and other areas at danger. Pakistan, the fifth-most populous nation in the world, used around 3.35 quadrillion BTU of energy in 2021, 91% of which came from non-renewable sources and 9% from nuclear and renewable sources. With an average annual growth rate of 3.33%, this energy consumption climbed from 1.83 quadrillion btu in 2002 to 3.35 quadrillion btu in 2021. It is therefore imperative that we acknowledge the urgent need to address this energy crisis by implementing robust energy conservation measures. Given the limited availability of non-renewable energy sources and the undeniable link between greenhouse gas emissions and climate change, the preservation of energy assumes paramount importance. By adopting energy-efficient practices, we can effectively mitigate the adverse effects of escalating energy consumption.

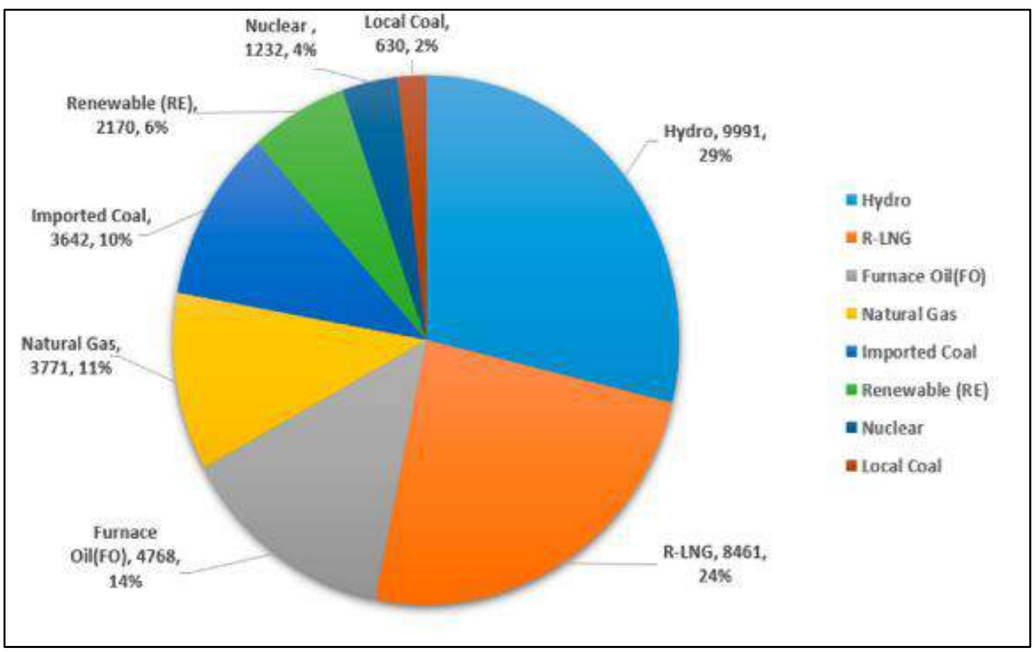


Figure 1.1: Pakistan total energy consumption by fuel type – 2021 [1]

Building emissions are one of the major contributors to energy-related emissions. Buildings utilise a huge amount of energy during their entire life cycle and produce a lot of emissions. Buildings also represent the energy used in the mining, processing, manufacturing, and transportation of the building materials, as well as the energy required in their construction and decommissioning. The life-cycle energy and emissions footprint of a building is made up of this embodied energy as well as the energy utilised during its lifetime. According to the United Nations Environment Program, buildings and their construction account for 36% of worldwide energy usage and 39% of energy-related carbon dioxide emissions per year. Buildings embedded carbon contributes roughly 11% of global emissions.

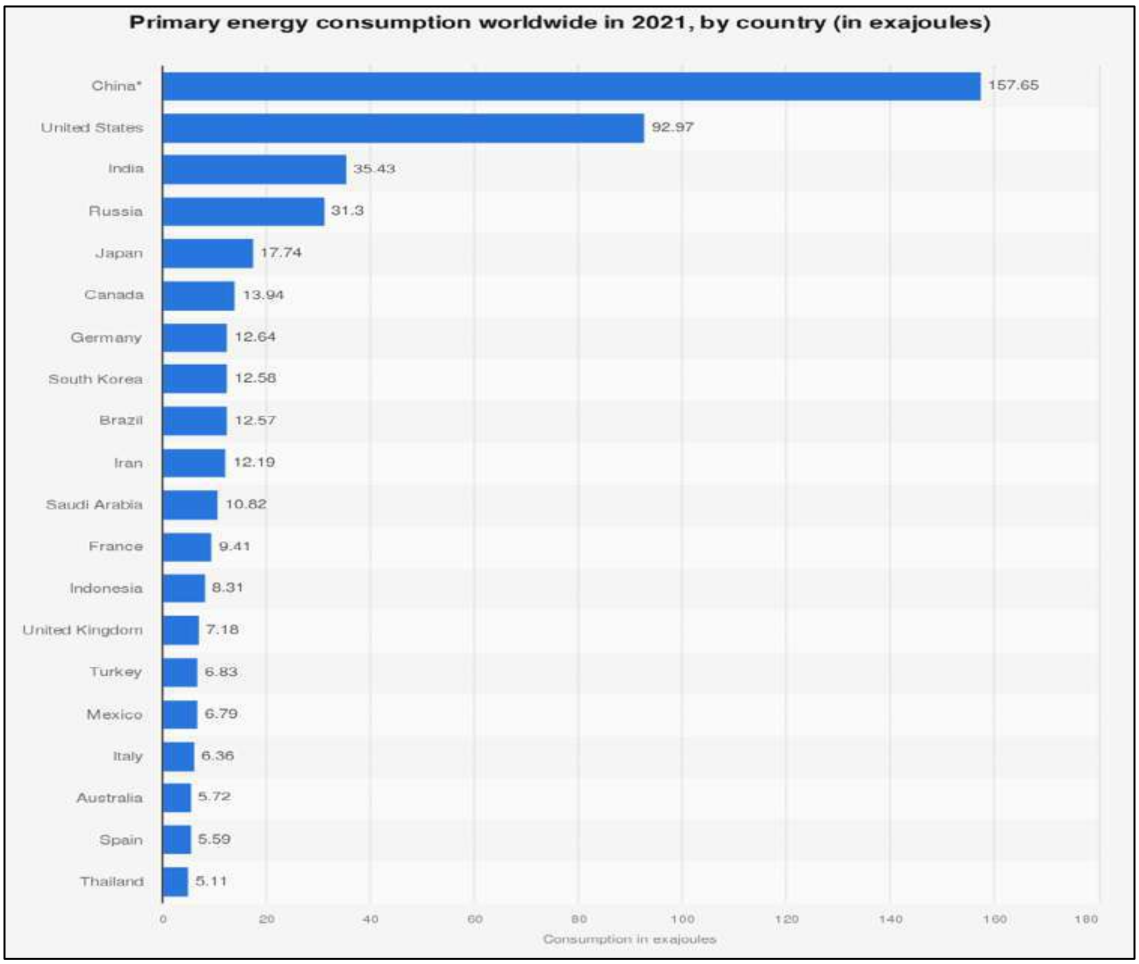


Figure 1.2: Primary energy consumption worldwide per country – 2021 [1]

## 1.2 Carbon Footprint

The quantity of $CO_2$ that a building creates while it is in use and throughout its operations is referred to as its carbon footprint. Both new construction and existing structures must take into account a building's carbon footprint. The whole group will be able to ensure that the building design has the least amount of a negative impact on the environment by educating not just ourselves but also clients and consultants.

The fundamentals of siting, solar orientation, retention, and proximity to public transit must be taken into account in order to significantly reduce the overall carbon footprint of our buildings. The decisions we make when selecting materials and tools are crucial. Using energy-efficient lighting systems, HVAC, renewable energy sources, and low-embodied carbon materials are a few strategies that have lately become crucial in the quest to lower a building's energy usage.

With its inherent cost advantages and income prospects, managing and lowering carbon footprints as part of a low carbon plan is becoming more and more significant in building design. Regarding this, there has been an increase in interest in creating zero energy buildings to achieve corporate goals, and in response to regulatory requirements, federal government agencies as well as many state and local governments are starting to move towards zero energy building targets.

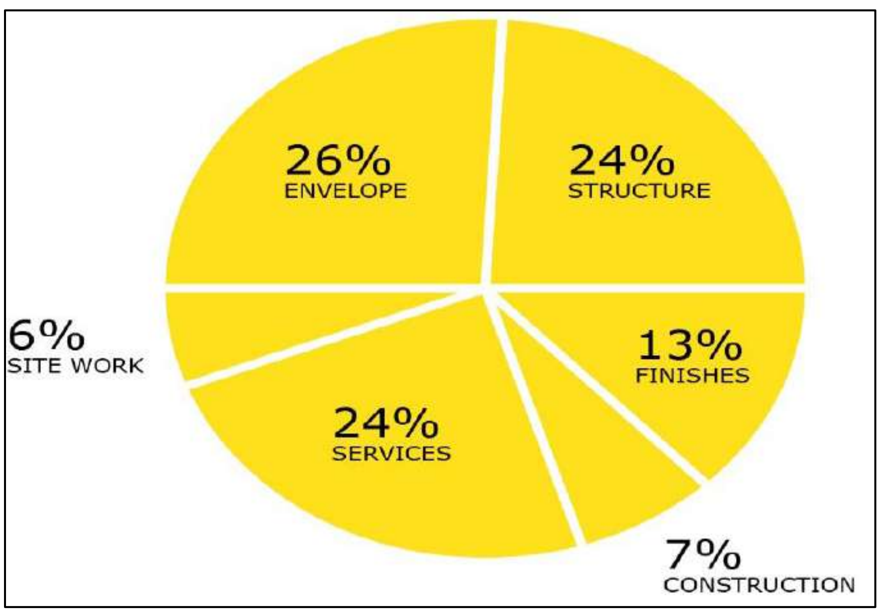


Figure 1.3: Figure illustrating carbon footprint [2]

## 1.3 Net Zero Energy Buildings

In order to reduce the use of non-renewable energy in the construction industry, a net zero energy building (NZEB) generates enough renewable energy to cover its own yearly energy needs. NZEBs employ all feasible methods to lower energy consumption via energy efficiency and include renewable energy sources that can provide all of the remaining energy requirements.

Lower environmental consequences, cheaper operating and maintenance costs, increased resilience to power outages and natural catastrophes, and improved energy security are all noteworthy benefits of deploying NZEBs.

NZEBs use a combination of energy efficiency and renewable energy production to limit their energy use to what can be generated onsite from renewable resources during a given time period. NZEBs have the power to drastically alter how buildings consume energy. We may explore the possibility of building NZEBs with materials recovered from industrial sludge in more depth.

### 1.3.1 Construction Materials Reclaimation From Industrial Sludge

A substitute method of producing construction materials from other sources has been required due to the recent increase in demand for building materials. Sustainable construction materials are being developed in order to fulfill the growing demand while minimizing the environmental impact. Waste management and recycling into environmentally friendly building materials has shown to be an effective substitute for waste disposal, reducing both economic and environmental burdens. This approach not only helps in conserving natural resources but also mitigates the carbon footprint associated with traditional construction practices. The utilization of recycled wastes such as fly ash and SSD in products like bricks, aggregates, cement, ceramics, and glasses further enhances the sustainability of the construction industry. By promoting the use of these recycled materials, we can contribute to a more circular and eco-friendly construction ecosystem.

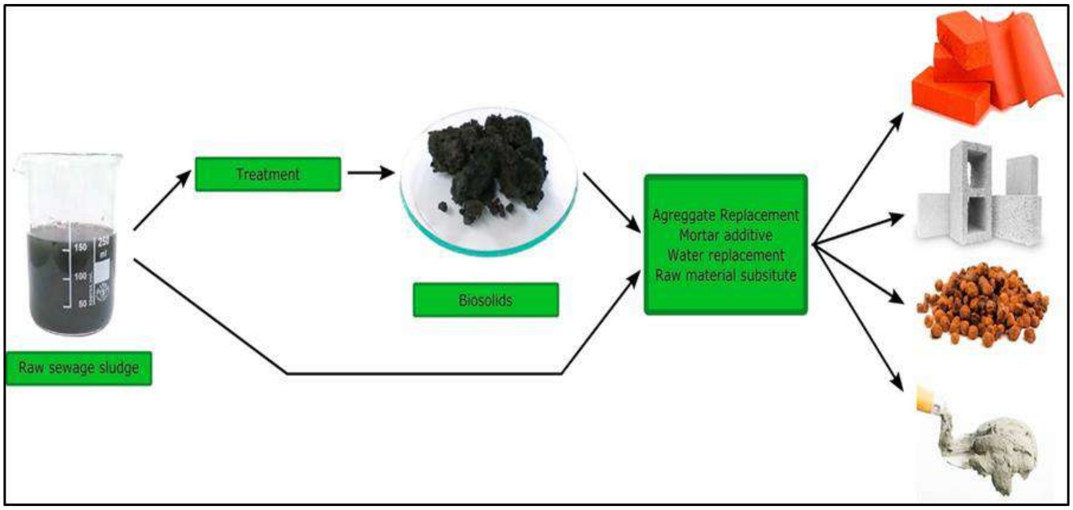


Figure 1.4: Represents the Uses of sludge for construction purpose [2]

### 1.3.2 Environmental Audit

By performing an environmental audit of a project's energy usage, which contributes significantly to a building's carbon footprint, we may further control the amount of energy used. Environmental auditing is essentially a technique for environmental management that compares the environmental impacts of various operations to predetermined criteria. Considerations for the land usage, acoustics, water quality, electricity, among other important contributing aspects, are all necessary. Early use of this technology during design enables us to take action to improve building efficiency.

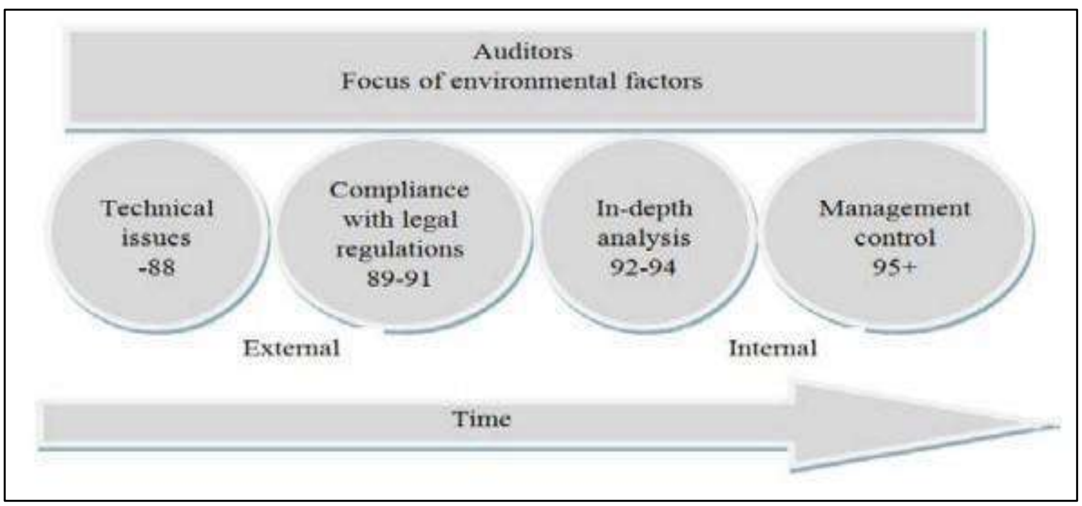


Figure 1.5: Depiction of how environmental audit changed over time [2]

## 1.4 Objective

This project's primary goal is to develop and create a net-zero energy educational building. By utilising recycled construction materials from industrial waste to be used in the structure, we want to push the limits of what is possible when designing a zero energy building. The softwares SketchUp Pro 2020 and Lumion 10 will be used to create a computer simulation of the structure. The building's energy usage is then evaluated using Autodesk Green Building Studio as part of an environmental audit, which will outline the project's results and additional research and development needs.

## 1.5 Need For Study

- We have to incorporate the term "SUSTAINABLE" into the building sector given the present situation where it is a need. The building sector wastes a lot of energy and valuable natural resources. B eginning with the selection of the building materials and ending with the amount of energy used to build the structure. Our project goal adheres to this objective and promotes sustainable development principles at every turn.
- In a time when waste production is a major problem, we seek to reuse the waste. Waste generation doesn't end with its creation; it continues to harm the environment because it is unavoidable. By encouraging hazardous emissions, contaminating the environment around landfills, raising the toxicity of water, and, of course, destroying enormous tracts of land unfit for habitation, improper waste management practises have contributed to the global decline. A source-based approach to waste reduction and recovery is recommended by experts, and both ideas have been covered here.
- The current scarcity of high-quality building supplies has ushered in a period in which not only essential resources and services, but even building supplies, are insufficient. Many places have become infertile and barren due to the over usage of clay, sand, and bricks. More of these resources being overtaxed would only hasten the destruction of the delicate equilibrium for which nature is now striving. We discover a viable and sustainable option th at satisfies the requirements of construction and Mother Nature by utilising recycled assets.

- Net zero energy buildings contribute to lowering carbon footprints, which eases the strain on the world. The term "carbon footprints" describes the amount of greenhouse gases that a person, place, or thing emits. These emissions are the main causes of global warming and have a big negative impact on the planet. By accounting at the very least for the energy used by the structure itself, the development of Zero Energy buildings would help reduce the The burden on the earth. A building that accounts for the energy it uses is required to have specific incentives that make it desirable to both the environment and the people who work in and use the building.
- The cost of building has already been significantly reduced by the reclamation of industrial waste. Nonetheless, the Zero energy standard favours simple and effective operation and maintenance. Over time, this dominance would inevitably result in capital conservation. Nowadays, sustainable development is regarded as necessary on a worldwide scale. Any development, whether physical or otherwise, must take care to prevent long-term injury or destruction, which would ultimately leave the environment or its resources unusable. This project focuses on the planning and design of a net zero energy educational building in Phase V Hayatabad, at the very heart of Peshawar, realising the importance of such a model implemented in educational institutions, where future generations are nurtured.

## 1.6 Scope of the Study

This project's primary goal is to promote sustainable development, which is urgently needed in the modern world. It places a focus on resource and energy efficient construction techniques. This project will primarily include the necessity for such a shift, the obstacles to adopting this strategy, implementation strategies, comparisons with existing approaches, current situations and developments in these fields, and of course the impact of the project on modern society.

The core of it involves three significant divisions. The first stage, or phase I, is choosing a location that will meet the project's objectives and prove suitable for the topic criteria. Phase-II of the development process entails the development of the building as a net-zero energy structure, with the replacement of building materials made from industrial sludge and the replacement and restructure of structural parts to increase energy efficiency. This is totally theoretical and only intended to be used as a benchmark against accepted norms. In order to determine the final outcomes, the last phase assigns a simulation of the planned zero energy educational facility together with improvised supplies. The goal of this project is to provide a real, workable solution for sustainable building that will advance the industry.

## 1.7 Limitation of Work

- The perception that creating zero energy efficient structures is expensive poses a constraint. However, analyses indicate that energy efficient buildings have a cost increase of only 8-10% compared to normal structures, which can be recouped within 10-15 years through lower operating expenses.
- The inclusion of industrial sludge in construction materials is a relatively new concept, and long-term consequences regarding toxicity, durability, and tensile strength are still being explored. Additionally, the strength requirements of concrete with sludge inclusion need further investigation before widespread implementation.
- While the project aims to create a zero energy building, the current data and results only support achieving a gold LEED rating, falling short of the platinum LEED rating required for true zero energy buildings. Continual monitoring and assessment are necessary to evaluate the performance of zero energy buildings in meeting net zero energy objectives effectively.

## 1.8 Thesis Organization

This thesis focuses on the comprehensive exploration of "Planning and Designing of Net Zero Energy Educational Building." The organization of this research is as follows.

Chapter 1 provides an overview of the background, motivation, and research objectives.

Chapter 2 examines energy consumption in buildings, sustainable design principles, and case studies of net zero energy buildings.

Chapter 3 outlines the site selection process, design considerations, software tools used, and environmental audit process.

Chapter 4 covers concept development, integration of energy-efficient features, construction timeline, and quality control. Results and analysis evaluate the energy performance and compare it to conventional buildings. The discussion interprets the findings and offers recommendations.

Chapter 5 summarizes the research, its implications, and suggests future research directions.

# Chapter 2

# Literature Review

## 2.1 Net Zero Energy Building

Ecology and the idea of net energy are closely related. Ecologist Howard Odum addressed economic difficulties in the paper "Energy, Ecology, & Economics" by utilising ecological theories based on the basics of energy. According to him, "the net energy, which is that after the expenses of collecting and concentrating that energy are eliminated," is the energy that has the most value to society. He argued that all kinds of life are built on transformable energy. He opened the door to understanding how various elements of an entire ecosystem interact with one another by seeing ecology as a sizable, integrated ecosystem.

The economic crisis of the 1970s was significantly influenced by the energy problem. The 1973 OPEC oil embargo caused a 350% increase in oil prices, which had tremendous impact on the whole economy. The economic crisis intensified despite efforts by industry, government, and entrepreneurs to encourage energy conservation among consumers. The first energy crisis had a significant impact on the construction sector. Many techniques for increasing a building's energy efficiency have developed since 1973. The Danish zero-energy home, which was developed under the direction of Professor Vagn Korsgaard from the Technical University of Denmark, was one of the earliest net zero construction experiments. This project, which was located on a university campus outside of Copenhagen, took place between 1976 and 1977. The results of this experiment were crucial in the creation of modern energy-efficient buildings, was used for simulations and measurements aimed at improving building services and parts. The structure included adjustable thermal insulation in front of the windows, a system for recovering heat from exhaust air, and a solar heating system that employed 42 $m^2$ of flat plate collectors and a 30 $m^3$ hot water storage tank. The usage of the term "net zero" in an energy-efficient construction experiment may have started with this project.

To make its usage easier, DOE created a standard national definition for zero energy buildings, together with accompanying terminology and standards. State and local governments, as well as federal government agencies, have started working towards zero energy building objectives, although definitions of what zero energy buildings are have differed from area to area and from one building expert to another. In order for governments, utilities, or private organisations to recognise or promote zero energy buildings, a widely agreed definition of zero energy building metrics and boundaries must be established. By identifying a number of parameters that vary between ZEB definitions, A.J. Marszal et al. present various interpretations of a relatively straightforward concept. These parameters include the metric, the period, and the types of energy included in the energy balanced along with options for renewable energy supply, the connection to the energy infrastructure, and energy efficiency. They also include requirements for indoor climate control and building-grid interaction. A National Renewable Energy Laboratory paper from 2006 noted that "a zero energy building can be characterised in different ways, depending on the boundary and the metric" due to the lack of agreement on a single definition. These terms net zero energy building (NZEB), net zero site energy (NESE), net zero source energy (NZSE), net zero energy cost (NZEC), and net zero energy emissions (NZEE) were developed and eventually adopted as the standard definitions in the US.

The requirement for creating effective systems to take into account the constantly increasing energy consumption and the pressing desire to save as much energy as possible increased as ZEBs gained popularity. The advancement of NZEB's sustainable development got actively sought. A power production system, a solar heating system, a solar cooling system, a renewable source heat pump, and other established energy-efficient measures for NZEB were all examined by S. Deng et al. in his investigation of international efforts and politics. They also stress how the energy system may become a focal point for future enhancements to NZEB performance. With the help of renewable energy, NZEB's energy system, which includes its HVAC, DHW, and on-site power production system, might be more efficient. The three areas of research - energy storage, load matching and grid interaction along with the smart grid were seen to advance the sustainable growth of NZEB.

With the expanding worldwide effort towards near-zero and net-zero energy buildings, the significance of the function of building materials and associated embodied energy or CO2 emissions increased. The issue of carbon dioxide emissions into the atmosphere is the focus of

Elena Perlova and colleagues, who link a significant portion of this to emissions from housing stock. This work develops a low energy consumption building to address this problem head-on. A vestibule is included at the entry to prevent extra heat loss, and it is planned and built with measures to guarantee ideal building orientation, glazing of facades, and measures to preserve buildings for an overall sustainable and healthy ecological environment.

According to the European Commission (2014), the construction industry is responsible for around one-third of all waste production and is linked to environmental pressures that develop throughout a building's life cycle, including during building construction, usage, refurbishment, and waste management. ZEBs that were very energy efficient were able to develop and become extensively used. The major goal of this is to reduce material waste during the life cycle assessment of the building. By incorporating recycled and waste materials into the construction materials, Alessandro Tallini et al. highlighted changes in thermal characteristics (thermal conductivity, specific heat, and density). The research also examined the technical viability of using inert waste materials from the combustion of municipal solid waste or solid recovered fuel. In this study, the use of waste materials in the production of thermal building insulation was investigated. Examples included modified concrete with the addition of glass, wood, and plastic waste, rubber-added bricks, lightweight cement composites based on rubber waste, and lightweight aggregate made from fly ash and plastic waste.

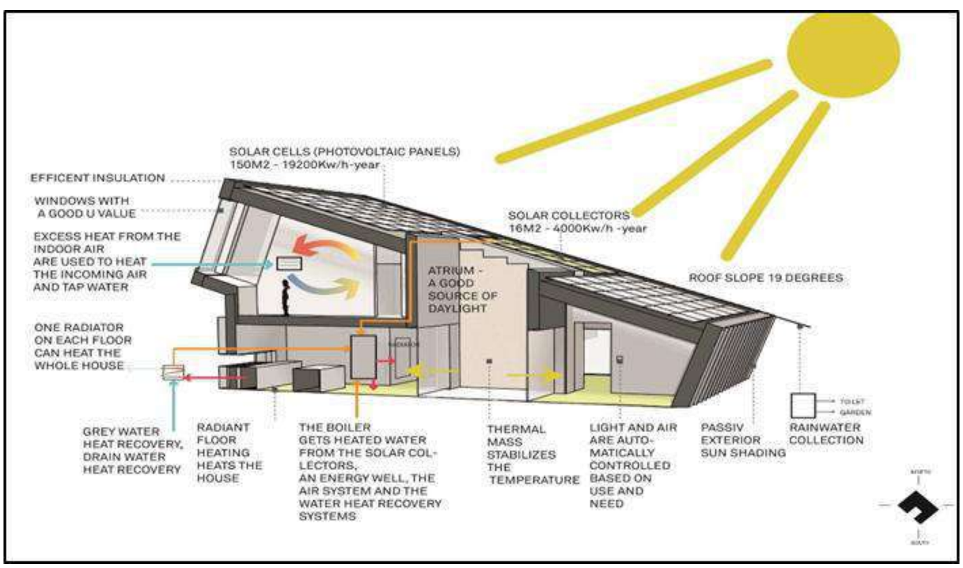


Figure 2.1: Depiction of a zero energy house [3]

## 2.2 Reclamation of Construction Materials From Industrial Sludges

A different method of producing construction materials from other sources is required due to the recent surge in demand for building materials. The development of sustainable construction materials has received attention in order to fulfil the rising demand. The construction industry is using more and more advanced building materials, which has prompted studies into their environmental effects and compliance with regulations when waste is utilised to create sustainable building materials.

In an effort to create a more sustainable world, researchers have tried to recycle and repurpose waste. Red mud, fly ash, blast furnace slag, industrial steel dust, and other sewage sludges are some of the wastes that have been utilised in the search for sustainable building alternatives. It has been demonstrated that recycling or reusing such waste to create sustainable building materials is an effective way to address the disposal and environmental issues (O. A. Johnson et al., 2014).

Sewage sludge ash (SSA) has been researched for usage in a variety of construction applications, including brick and tile components, cement production raw materials, concrete and mortar aggregates, synthetic lightweight material components, and alternatives for sand and/or cement in road pavement (Marzena S et al., 2015).

Industrial waste has also been tried to be used in the production of bricks, including paper processing waste, cigarette butts, fly ash, textile effluent treatment plant sludge, polystyrene foam, plastic fibre, straw, polystyrene fabric, cotton waste, dried sludge collected from an industrial wastewater treatment plant, rice husk ash, granulated blast furnace slag, rubber, Kraft pulp production waste, limestone dust, and wood sawdust (O. A. Johnson et al., 2014).

The primary components of phosphate sludge include marls, lime stone blocks, silex bed, silex nodule, marls and clays, and silicified limestone, all of which have a high potential for reuse as marble mosaic floors, mortars, concrete, and natural stone goods slabs for floors and staircases (Rachid Hakkoua et al., 2016).

### 2.2.1 Waste Sludge in Bricks Production

In order to create bio-bricks, Alleman and Berman (1984) combined sludge (15–25%) with clay and shale. When Yague et al. (2002) looked into the possibility of using dry pulverised sludge (2%) in the manufacturing of bricks, he found that the bricks' compressive strength, porosity, and water absorption were all much higher than they were in bricks without sludge. Chih-Huang et al. (2003) studied bricks made from sludge from industrial waste water treatment plants and found that the amount of sludge and the fire temperature affect the brick quality. With 10% sludge with 24% moisture content created in the moulded mixes and burnt at 880–960°C, high-quality bricks may be made. In comparison to traditional clay bricks, the lightweight bricks produced by Kung-Yuh et al. (2009) by sintering mixtures of dried water treatment sludge and rice husk had a low bulk density, stronger compressive strength, and better water absorption.
The production of bricks with clay and textile laundry wastewater sludge (20%) was suggested by Luciana et al. (2011). The bricks demonstrated the best mechanical properties, and the results of the leaching test established the product's safety without having any negative health effects on the consumer. Sludge, industrial wastes, including rice husk ash (RHA) and silica fume (SF), and agricultural wastes were all investigated by Badr et al. (2012) as potential replacements for clay brick. Products that contained 25% SF and 50% sludge outperformed traditional bricks. According to Kulkarni et al. (2013), replacing 10% of the fly ash in fly ash bricks with bagasse ash results in satisfactory compressive strength. Moreover, it lowers the building's seismic weight, brick cost, and density. In order to create "Greener Eco-friendly Bricks for Building," Prasad et al. (2014) demonstrated that clay bricks compressive strength may be enhanced by mixing in 25% of granite dust and 55% of fly ash, which reduces the water absorption capacity of the bricks.

### 2.2.2 Waste Sludge as Artificial Aggregate

Tay et al. (2002) employed clay and dried industrial waste with minimal organic content, which were both crushed into a fine powder before being combined with water to make a paste. The resultant paste was shaped into aggregates and then hot-sintered. The artificial sludge clay aggregates demonstrate larger porosity and lower density when compared to granite aggregates, according to their performance evaluation. Chou et al. (2006) investigated the possibility of using a mixture of sintered sewage sludge and sludge ash to create synthetic aggregate. According to the findings, sewage sludge ash and clay were better combined to make normal weight aggregate, while a mixture containing 20–30% sewage sludge was more suitable to produce lightweight aggregate.

In comparison to traditional goods, Shane et al. (2008)'s sustainable, low-energy building solutions that make good use of Incinerated Sewage Sludge Ash (ISSA) shown greater reactivity and workability. The use of lime sludge, which considerably enhanced the mechanical characteristics and durability, is explored by Yu et al. (2009) [39].

### 2.2.3 Waste Sludge as Cement-like Material

Tay et al. (2002) looked at how digested and solubilized sludge may be used to make cement-like material. Limestone powder and dried sludge were combined to create the specimens. The combination that produced was crushed up and burned. The results revealed that sludge cement required more water to set quickly than regular cement. Sewage sludge pellets (SSP) may be used as a substitute for raw materials in the manufacture of Portland cement, according to research by Monzo et al. (2004). According to the findings, the mortar with 15% sewage sludge ash has a comparable compressive strength to the reference mortar.

In 2005, Valls et al. looked at the use of dry sludge as an addition in concrete. Up to 10% of the fine sand in the concrete mix was dry sludge. Sludge combines with cement to create a binding matrix, therefore it was advantageous. In order to assess long-term performance, Yague et al. (2002) looked at the durability of concrete samples that had sludge added to the mix. After being subjected to accelerated impacts, the samples durability was compared to that of reference concrete, according to the results.

### 2.2.4 Waste Water in Concrete Mixtures

Several international organisations advise using recycled grey water in concrete manufacturing due to the worldwide water crisis. Using potable and grey water, concrete cubes of grades M-20, M-25, M-30, M-35, and M-40 were cast, and on days 7 and 28, their compressive strength was evaluated. Concrete with grey water has values for compressive strength that are almost identical to or slightly lower than concrete with potable water (R.T. Peche et al, 2014). Sludge water was compared to tap water in the making of concrete by Chatveera et al. In comparison to specimens prepared with tap water, those made using tertiary treated wastewater show greater strength.

The use of different types of sludge in the building sector can indeed provide a viable technological solution while meeting material requirements in accordance with existing regulations and considering environmental and economic issues. By utilizing sludge as a resource, we can address waste management challenges, reduce the demand for traditional raw materials, and promote environmental sustainability.

One of the key benefits of incorporating sludge in the building sector is the potential to solve waste management problems. Sludge, which is generated from various industrial processes, wastewater treatment plants, or agricultural activities, is often considered a waste product that requires proper disposal. However, by treating and processing sludge, it can be transformed into a valuable material for construction purposes. To ensure that the use of sludge in construction meets regulatory requirements and maintains material standards, it is important to conduct thorough environmental audits. These audits assess the environmental performance of buildings, taking into account factors such as energy efficiency, resource utilization, waste management, and overall ecological impact. By conducting such audits, we can ensure that sludge-based materials meet the necessary criteria and contribute to the building's efficiency and sustainability.

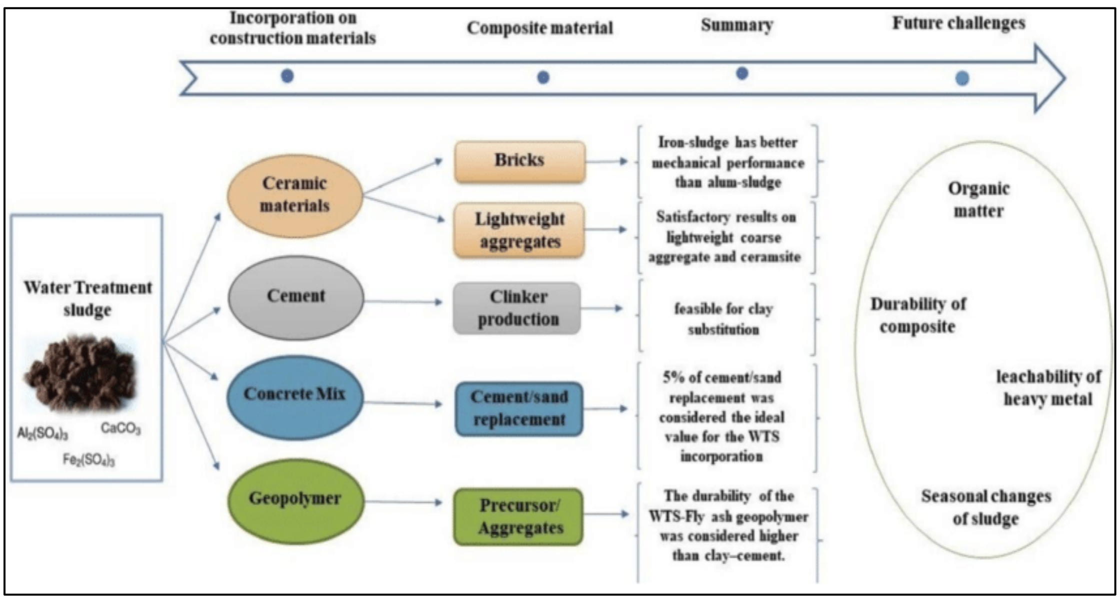


Figure 2.2: Overview on how sludge can be incorporated [3]

## 2.3 Environmental Audit

Without an environment audit, which is a notion that supports environmental issues and sustainable development and is a useful way to calculate how much energy is used, no design would be complete. Research by Sneana Ljubisavljevi focused a lot on sustainable development. The study employs analysis, synthesis, analogy, and continuity methodologies to explain the idea of such an audit. Specifically to come to a judgement regarding how an environmental audit affects environmental protection and development. A strategy for balancing advantageous activities with the environment in a way that benefits society and business.

The international standard ISO 14001 rules for environmental audit in compliance with general principles (ISO 14010), processes (ISO 14011), and environmental auditor credentials are frequently referenced throughout the study (ISO 14012). The report also discusses the methodologies, steps, and restrictions involved in an environmental audit.

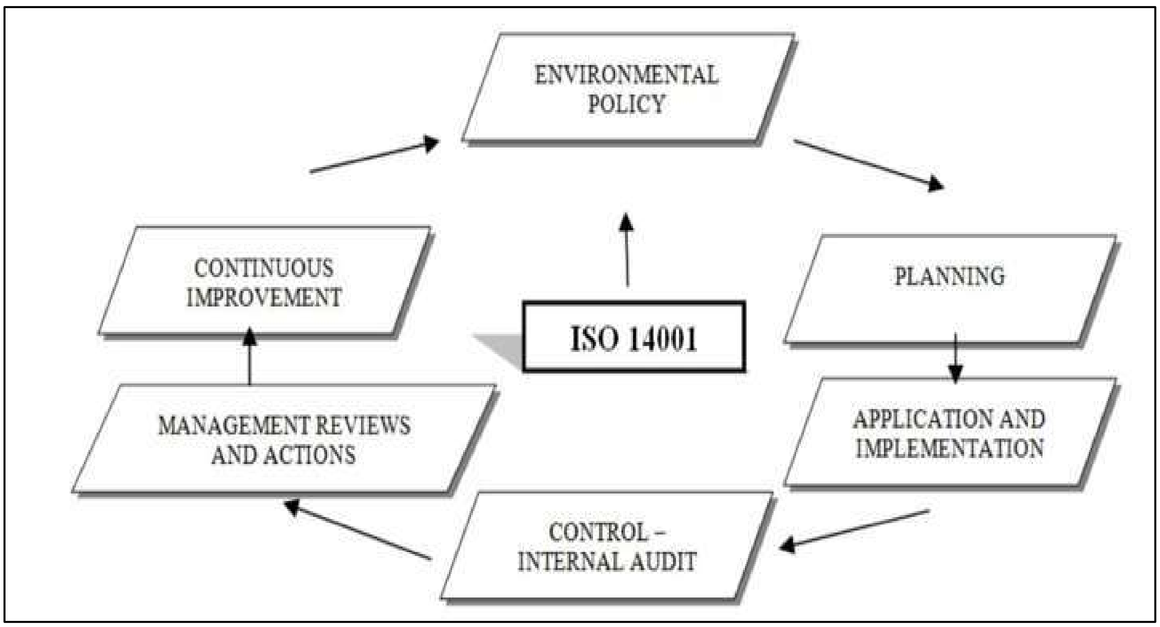


Figure 2.3: Basic approach to environmental protection [3]

Energy and Air Pollution Indices for Building Materials are ideally pre-determined to keep environmental regulations in mind from the very first stage of development, specifically in relation to building construction. Through a range of computational methods, COLE & ROUSSEAU concentrated on the variables that influence operational energy in buildings. In addition to providing examples of energy and pollution audits for four comparable commercial building assemblies with similar thermal resistances, their article explains the fundamental difficulties involved with environmental evaluation of the manufacturing and use of materials.

It is obvious that embodied energy is only one component of environmental auditing; in many situations, more important indications of the environmental cost of materials come from environmental emissions linked to non-energy related process emissions as well as energy usage by fuel type. Environmental audits can provide criteria for design decisions when selecting materials and assemblies with equivalent performance for a specific application. These audits may include energy usage for materials manufacture and installation as well as air pollution indices.

Selection and audit of the structure at the chosen site were the focus of research. In her essay, Elena Mazzola suggests a system for energy and environmental analysis that is integrated and dedicated to retrofitting historical buildings or current buildings. The Operations and Maintenance (LEED O+M) rating process serves as the foundation for the procedure. Nevertheless, there is no quantitative examination of the actions from an economic or financial perspective in this work. More analysis is required of the inquiry into supply costs, investment payback times, and comparisons to the Superintendent references.

The author Nicolae Todea focuses on the potential information that an environmental audit may provide to financial auditors. The following goals were taken into consideration in this study: the presentation of the environmental audit idea, the comparison of the environmental audit's phases with those of financial audit, and the restrictions on financial auditors involvement in environmental audit. It also contains a comparison of the phases of environmental audit and the financial audit procedures. The results drawn offer prospects for novel methods to environmental auditing and the participation of financial auditors in such auditing.

A case study that provides information on the Life cycle environmental evaluation of a school building in Northern India was adopted. According to the study, a thorough life cycle environmental evaluation of the facility was done to determine its energy usage and greenhouse gas (GHG) emissions. In order to analyse the energy use and greenhouse gas emissions of the MED building at NIT Hamirpur, which is located in the Indian state of Himachal Pradesh, LCA is utilised.

The construction, operation (usage), and maintenance phases make up the building's life cycle. It has been determined that producing energy (electricity) with minimal emissions and designing buildings that are energy-efficient throughout their occupancy phases are both crucial for energy efficiency. The purpose of this review's conclusion is to emphasise the significance of energy efficiency and the tremendous value of such measures in educational institutions for setting a good example for future generations.

## 2.4 Sustainable Development Goals

The proposed project directly aligns with Sustainable Development Goal 7, which aims to ensure access to affordable, reliable, sustainable, and modern energy. By planning and designing a net-zero energy educational building, our project contributes to the promotion of sustainable energy practices. Through the implementation of energy-efficient features, renewable energy sources, and efficient building design, we aim to reduce energy consumption and reliance on non-renewable sources.

Furthermore, our project is also linked to Sustainable Development Goal 11, which focuses on making cities inclusive, safe, resilient, and sustainable. By designing an educational building with sustainable features, we contribute to creating a sustainable and resilient urban environment. The integration of green spaces, efficient water management systems, and environmentally friendly materials enhances the overall sustainability and livability of the educational facility.

Lastly, our project addresses Sustainable Development Goal 13, which urges urgent action to combat climate change and its impacts. By developing a net-zero energy building, we actively contribute to reducing greenhouse gas emissions and mitigating the negative effects of climate change.

# Chapter 3

# Methodology

## 3.1 Steps Involved

The process comprises several key steps to ensure effective planning and designing of a net-zero energy educational building.

### 3.1.1 Selection of Site

Selecting a site that would meet the project's standards and prove appropriate for the subject criteria was one of the biggest hurdles. After much consideration, the centre of Peshawar's Hayatabad Phase V was chosen. The creation of a Net Zero Energy Educational Building in Hayatabad would serve as a prime illustration of how effective sustainable development techniques are for future generations. Using AutoCad 2020 software, the main structure's and the hostel's plans were created. The number of classrooms, fans, LED, S, projectors, and water storage facilities, among other architectural specifics, were also identified.

### 3.1.2 Incorporation of Industrial Sludge

We have investigated the potential for using industrial sludge in construction materials by studying many research articles in order to further include the element of innovation into the Project. This has given us a unique perspective on the idea of sustainability. The quantities of various kinds of industrial sludges included in construction materials were shown using various pie charts. This promotes sustainability by lowering building costs while simultaneously reducing the pollutant burden. The inclusion of industrial sewage reinforces the idea of sustainable development right from the start, furthering the project's mission.

### 3.1.3 Development of the Building as a Net Zero Energy Building

The following steps have been followed towards the establishment of a net zero energy educational building now that the relevant information and inputs have been obtained:

- **Orientation of the Building**

  The installation of solar panels should be oriented to maximise solar energy absorption. In order to limit the use of artificial lighting and ventilation systems, it is crucial that maximum ventilation and light be achieved through this. The building has been turned south in order to reflect this.

- **Thermal Mass Flooring**

  The amount of sun radiation that is absorbed by the floors will be reduced with the implementation of thermal mass floors and less heat will be released later, when it is cooler.

- **Double Glazed Windows**

  They play a big part in determining what critical equipment such as fans, lighting, cooling systems, etc. is needed.

- **Exterior Rain Drip Guard Over Windows**

  Windows have exterior rain drip guards installed over them at a suitable depth to shield them from water damage. Rainwater is collected in these guards and sent by pipe to the underground tank.

- **Solar Panel Implementation**

  In order to meet the building's energy needs, 60 solar panels with 450 watt capacity have been installed on the main university building, the hostel, and the multipurpose hall.

- **Parking Lot Solar Canopy**

  To provide on-site energy that can lower energy bills, create shadier environments, and cut $CO_2$ emissions, 450 watt solar panels are deployed over the whole parking lot.

- **Piezoelectric Strips**

  Yellow colored Piezoelectric strips are provided. These strips produce electricity when pressed by cars and pedestrians.

- **Light Emitting Diode(LEDs)**

  LEDs have been employed to make up for CFLs' difficult disposal and frequent environmental impact.

- **Brushless Direct Current (BLDC) Fans**

  As BLDC fans use less energy than conventional fans, they have been employed.

- **Rain Water Harvesting**

  A rainwater harvesting system has been installed in the structure, allowing for even more water saving.

- **Grey Wter Treatment**

  Measures have been put in place to lower the building's water usage while also making it more energy efficient.

- **Open Green Spaces**

  To enhance the building's thermal efficiency, open green areas are provided all throughout.

- **Industrial Sludge Incorporation**

  Industrial sludge construction materials are used as alternatives to common building supplies.

- **Low Toxicity Paints**

  With regard to ZEBs, volatile organic compounds have their own reasonable significance.

### 3.1.4 Development of a Computer Simulation

One of the most widely recognized and highly regarded software for building modeling is SketchUp Pro 2020. It provides users with the ability to annotate models with 2D drawing features and design buildings and their components in a three-dimensional environment. SketchUp offers different categories of items, including System Families, Loadable Families/Components, and In-Place Families, allowing users to create various elements of the building. Users can import pre-existing models from other applications and construct detailed and realistic families of objects, ranging from furniture to lighting fixtures.

In addition to SketchUp, we utilized Lumion, a powerful 3D rendering software, to enhance the visual appeal of our designs. Lumion offers an extensive collection of tools, materials, and creative effects, enabling users to create stunning visualizations. It provides the flexibility to incorporate beautiful sky, water, grass, materials, plants, people, trees, and various other objects, bringing the designs to life.

The design process involved integrating the building plans developed in AutoCAD 2020 with SketchUp Pro 2020. By linking the plans, we were able to seamlessly transfer the architectural details into SketchUp. This allowed us to incorporate specific elements essential for achieving a Zero Energy Building, such as double-glazed windows, energy-efficient lighting (LEDs), energy-saving fans (BLDC), solar panels, and systems for gray water and rainwater harvesting. The detailed 3D renders of the building were then created using Lumion 10 software, showcasing the project's design in a visually appealing and realistic manner.

By leveraging these advanced software tools, we were able to streamline the design and construction process, ensuring accurate representation, efficient collaboration, and effective communication of our net-zero energy educational building project.

### 3.1.5 Performance of an Environmental Audit

An environmental audit plays a crucial role in assessing the efficiency of the building and quantifying the benefits in terms of energy savings, cost reduction, and environmental preservation. It serves as a valuable tool for comparing the performance of the Net Zero Energy Building (NZEB) with conventional approaches. The audit involves several calculations, including:

1. Determining the energy consumption of alternative, yet equally effective, energy-efficient substitutes.

2. Comparing the energy usage of conventional appliances with their energy-efficient counterparts.

3. Contrasting the energy consumption between traditional equipment and energy-efficient alternatives.

4. Calculating the potential solar energy generation of the NZEB.

5. Assessing the water usage after implementing a grey water and rainwater collection system.

6. Estimating the quantity of building materials required, considering the inclusion of industrial sludge.

By conducting these calculations and analyzing the results, we gain valuable insights into the environmental impact and sustainability performance of our net-zero energy educational building. This information helps us make informed decisions and further optimize the design and operation of the building to achieve our sustainability goals.

# Chapter 4

# Results and Discussions

## 4.1 Planning and Designing

The planning and design of a net-zero energy educational facility is the goal of this project. The facility houses the main university building, a hostel and a multi purpose hall. The building has been equipped with energy-saving technologies including double-glazed windows, thermal mass flooring, rainwater harvesting systems, solar panels, BLDC fans, and LEDs.

### 4.1.1 Site Selection

Site selection is a critical process that involves careful consideration of various factors such as location, transport network, site geograph+y, and topography to identify the most suitable site for the net zero energy educational building.

#### 4.1.1.1 Location

Street 22, Sector C3, Phase V , Hayatabad Peshawar.

Figure 4.1: Site location depicted in google earth maps *(Google Earth Maps)*

### 4.1.1.2 Transport Network

The transportation network surrounding the chosen site is shown in Figure 4.2.

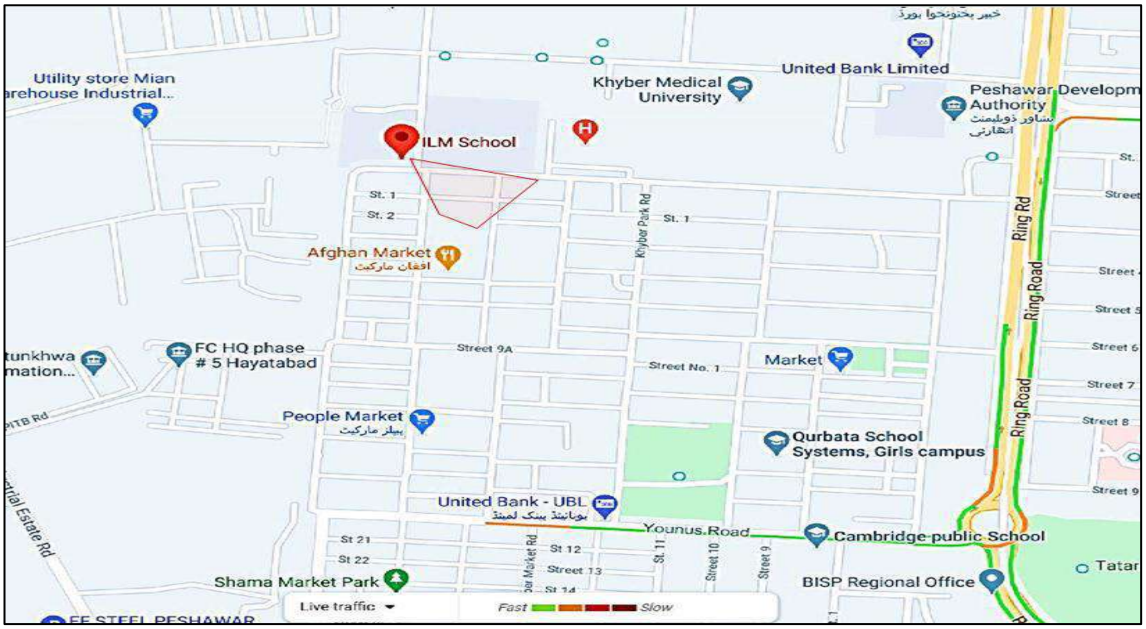


Figure 4.2: Visulaizing the transport network configuration *(Google Earth Maps)*

### 4.1.1.3 Site Geometry and Topography


Figure 4.3: Satellite view displayed *(Google Earth Maps)*

#### 4.1.1.4 Environmental Conditions

The Figure 4.4 depicts the environmental conditions such as wind direction, drainage, climate, noise pollution of Hayatabad Peshawar.

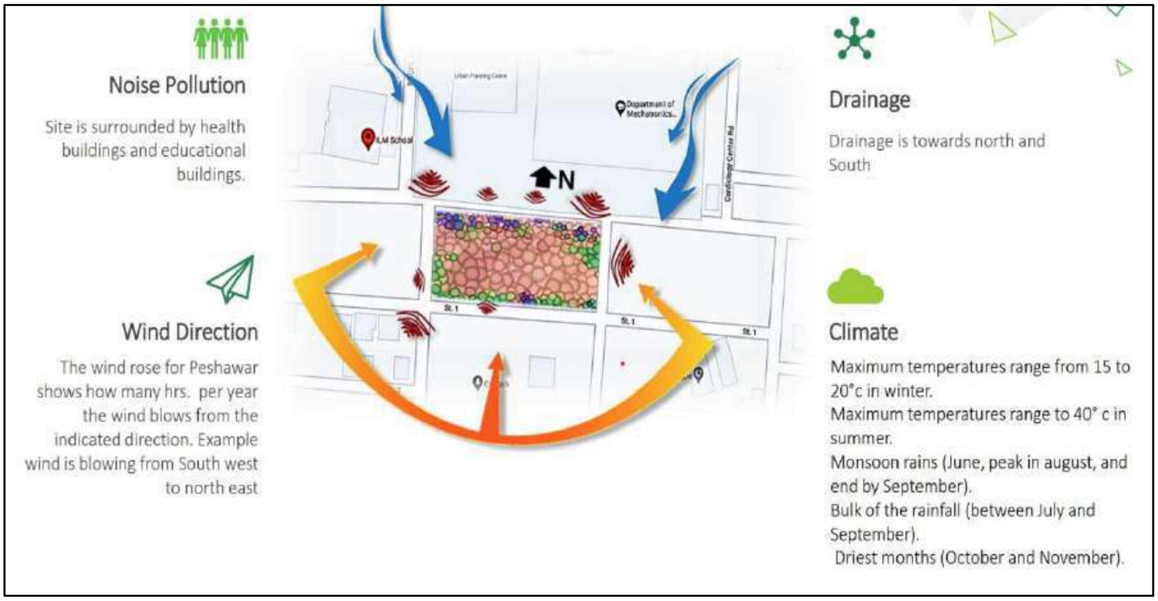


Figure 4.4: Depiction of Environmental Conditions *(Google Earth Maps)*

#### 4.1.1.5 Temperature

Regional temperatures in meso and macro areas as depicted in graphs shape the thermal environment and inform the planning and design of the net zero energy educational building.

Table 4.1: Depiction of Meso and Macro Analysis

| **Meso Analysis** | **Macro Analysis** |
|---|---|
| Gul Bahar 23 km | Mardan 78 km |
| Arbab Niaz Stadium 19 km | Nowshehra 57 km |
| Peshawar City 13 km | Islamabad 204 km |
| University Town 3 km | Abbotabad 223 km |

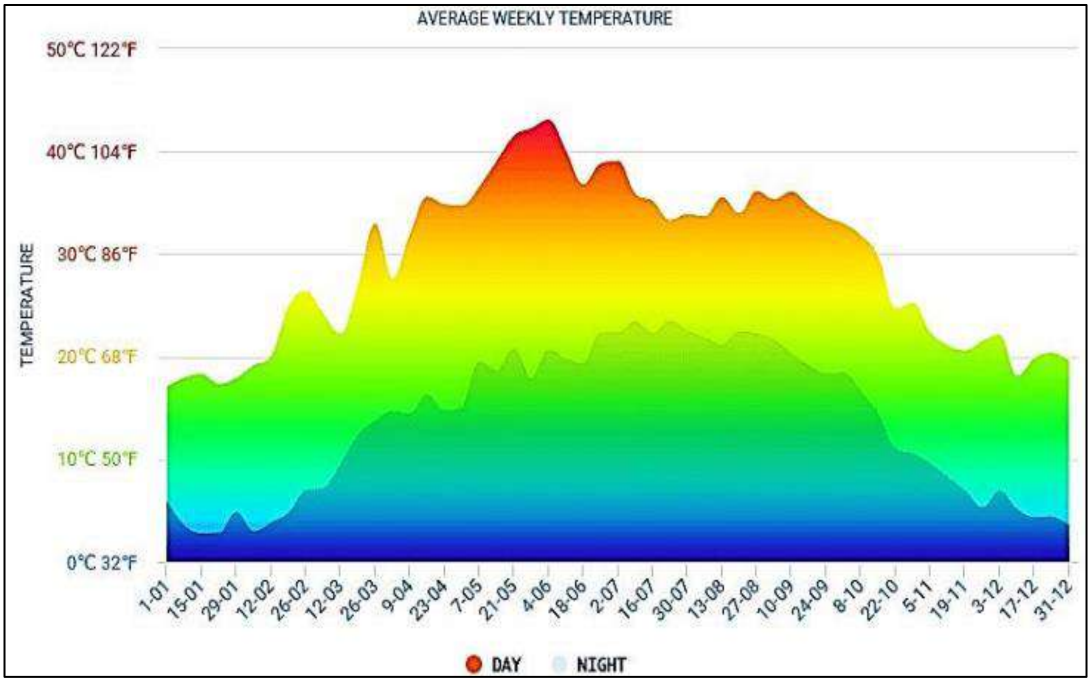


Figure 4.5: Selected site's meso analysis *(Pakistan Meteorological Department,PMD)*

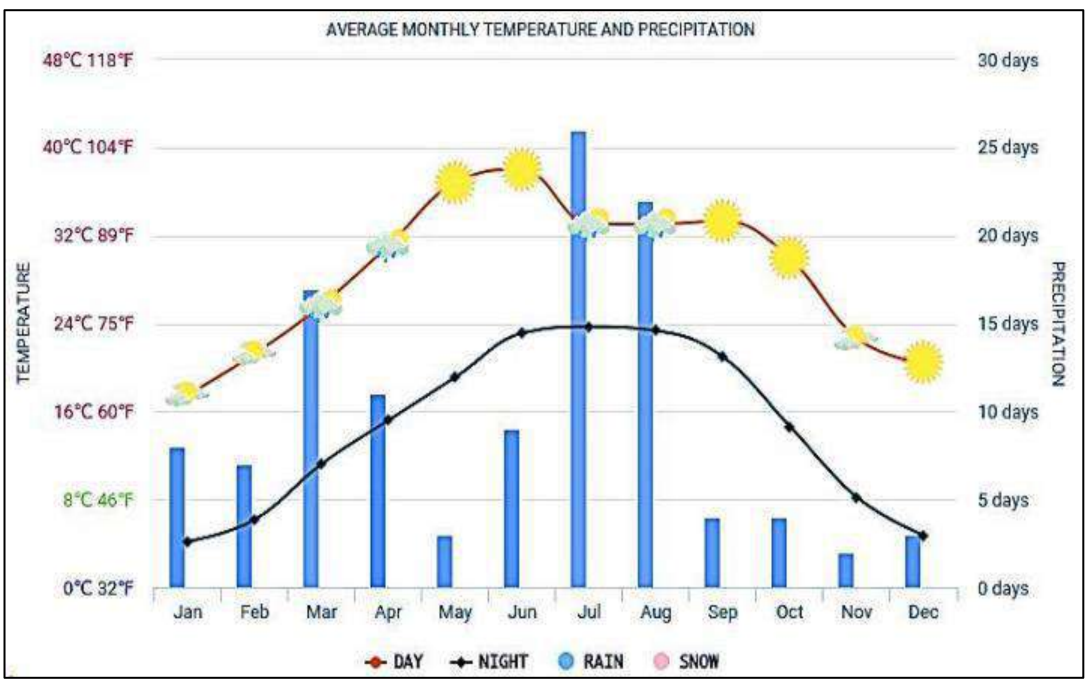


Figure 4.6: Macro analysis insights *(Pakistan Meteorological Department,PMD)*

#### 4.1.1.6 Neighbourhood

The Figure 4.7 illustrates the neighbourhood of the selected site.

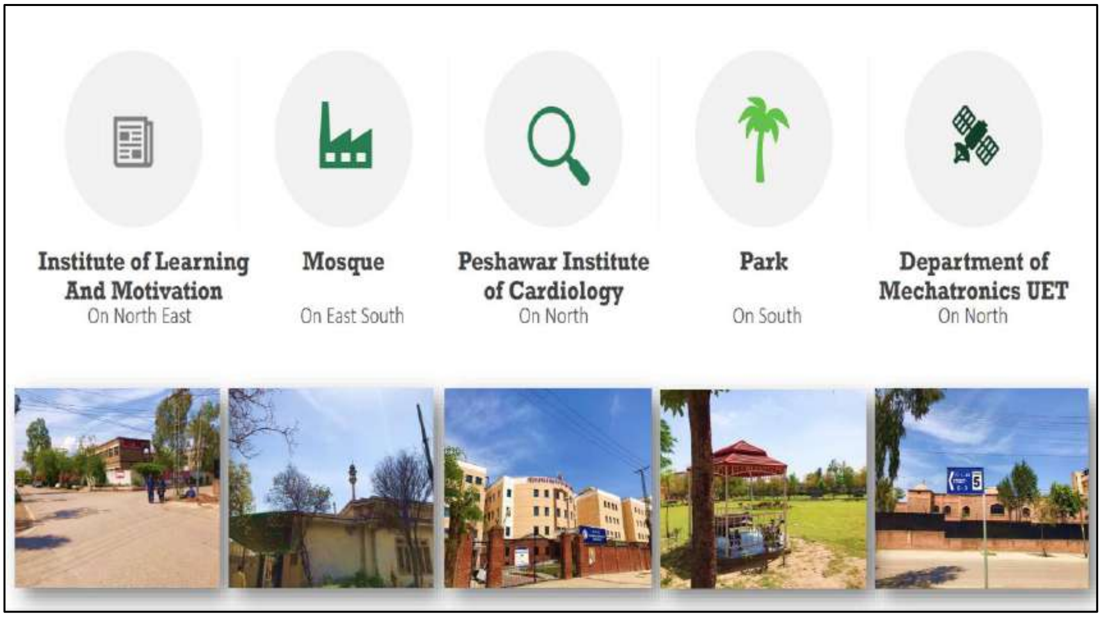


Figure 4.7: Visualizing the neighbourhood from different angles

#### 4.1.1.7 Side views

The Figure 4.8 portrays the side views of the selected site at Hayatabad Phase V Peshawar.

Figure 4.8: Depiction of side views of the location

### 4.1.2 Autocad Plans and Sections

Autodesk AutoCad 2020 software has been used to create the detailed floor plans and sections for the main university building, the hostel and the multipurpose hall. The main building houses the admission office, the head of department office, the reception office, the library, the teachers common room, the lecture halls, and various labs such as material testing lab, hydraulics lab, concrete testing lab, highway lab, soil mechanics lab etc. Green roofs are provided throughout the building as per the requirement of net zero energy building. The hostel has a dining area, kitchen, lobby, and guest rooms. According to the specifications of a net zero energy building, the rooms allocation in the plan has been done with careful consideration of the solar diagram. The plans also include the sizes of each feature of the university building, the multi purpose hall and the hostel.

#### 4.1.2.1 University Building Plans and Section

The various figures illustrating the comprehensive plans and sections of the university building are given below.

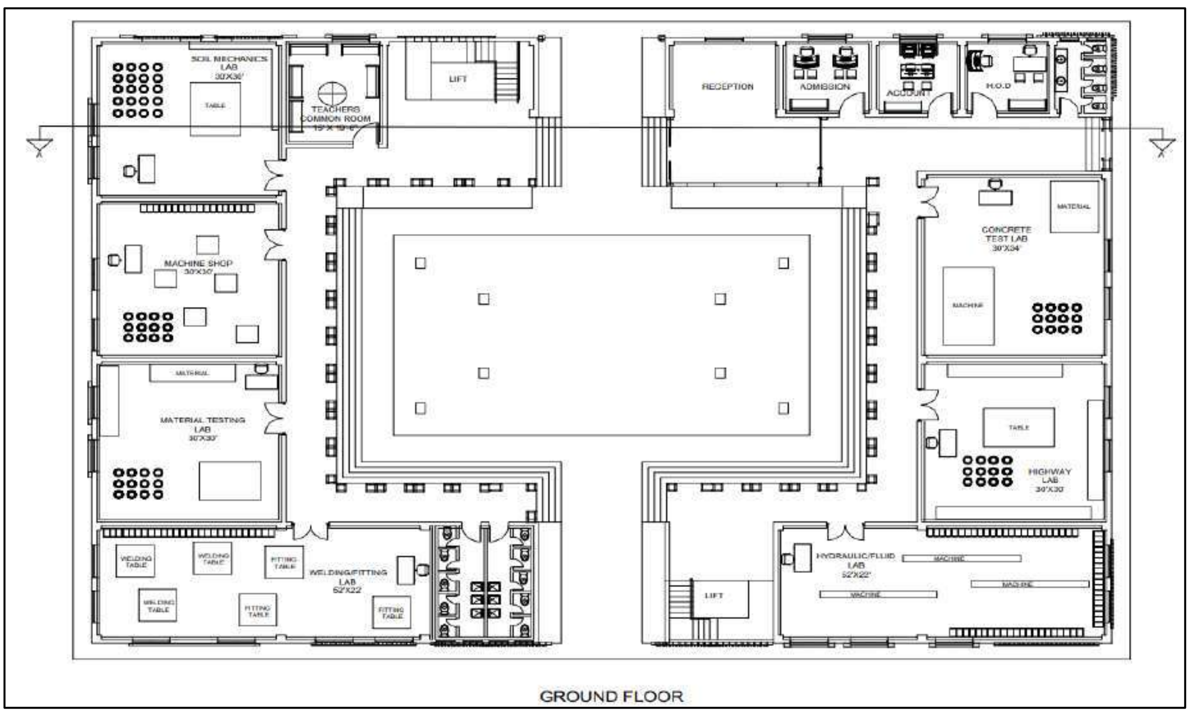


Figure 4.9: University building top view - Ground floor *(AutoCad 2022)*

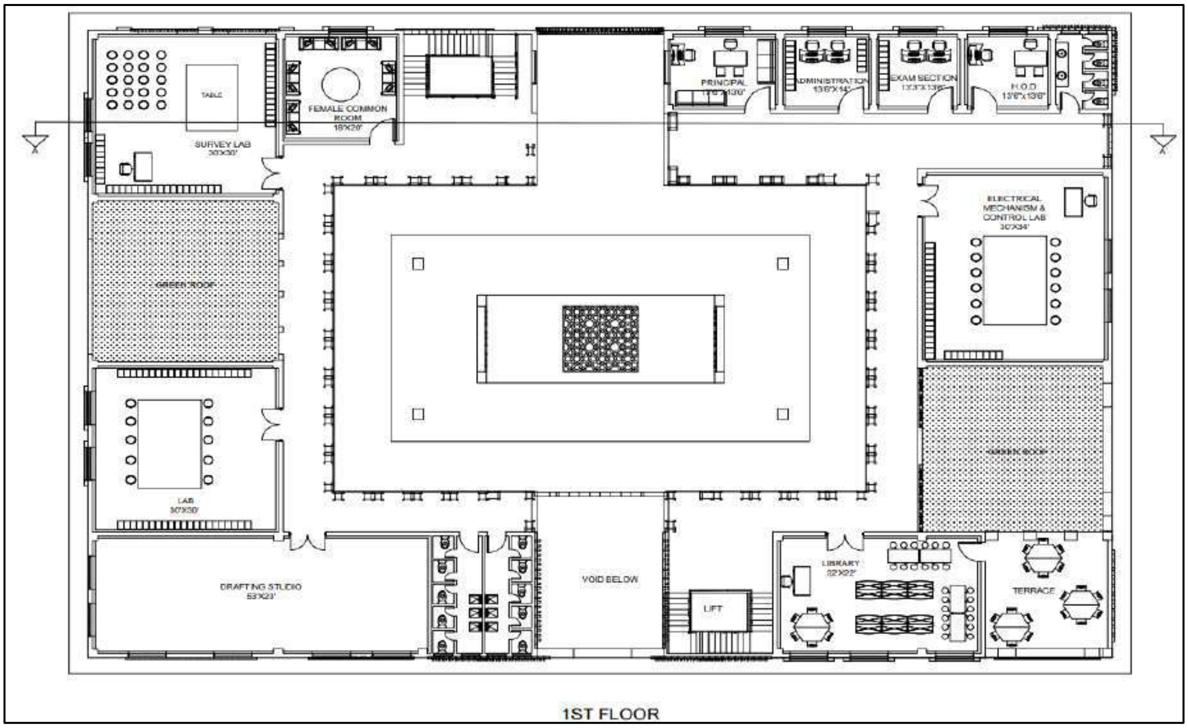


Figure 4.10: University building top view - First floor *(AutoCad 2022)*

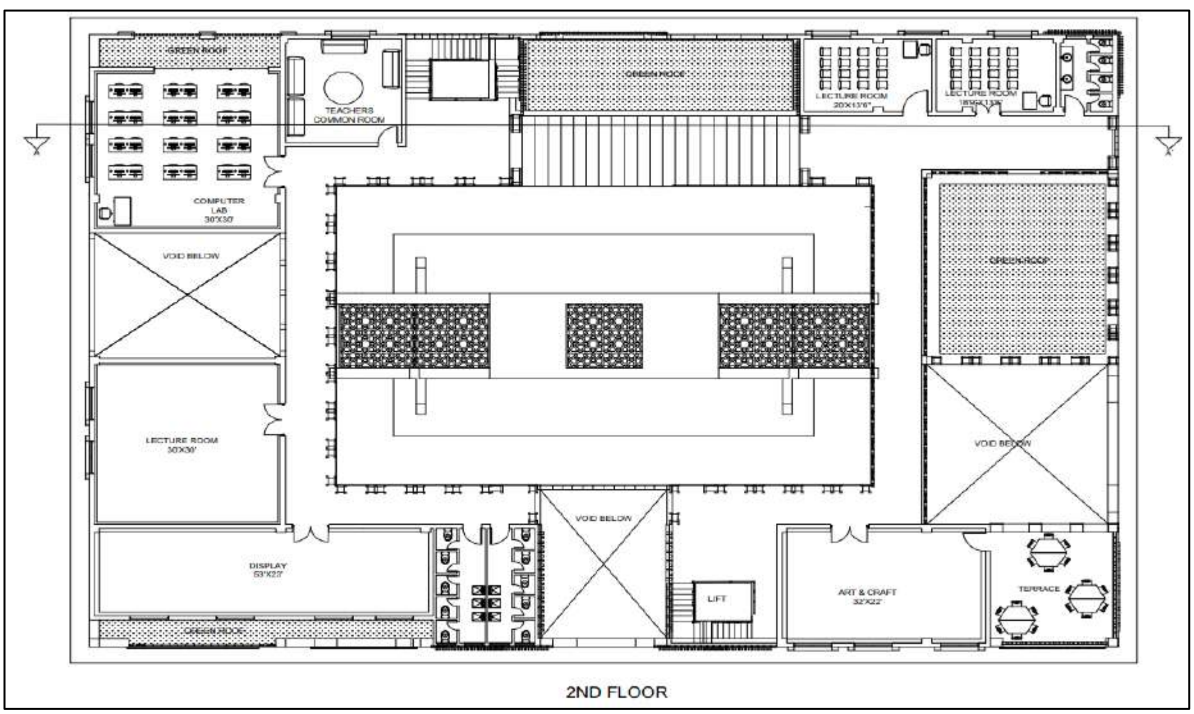


Figure 4.11: University building top view - Second floor *(AutoCad 2022)*

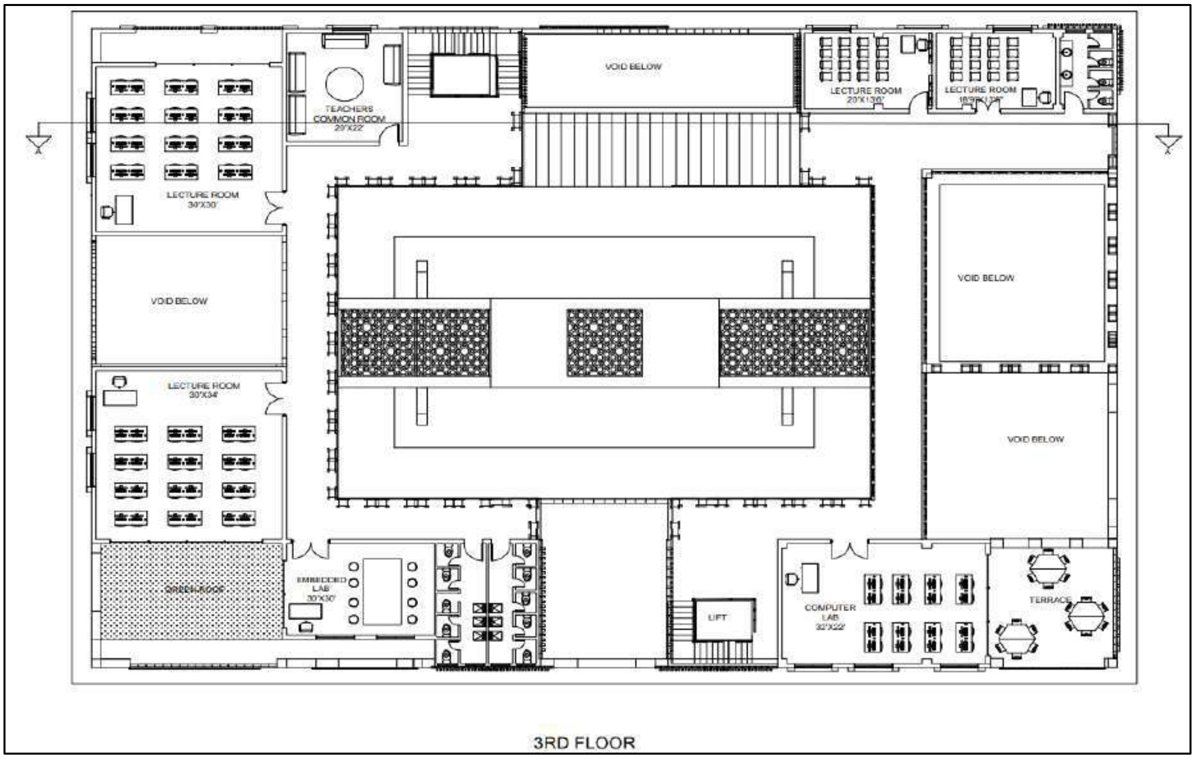


Figure 4.12: University building top view - Third floor *(AutoCad 2022)*

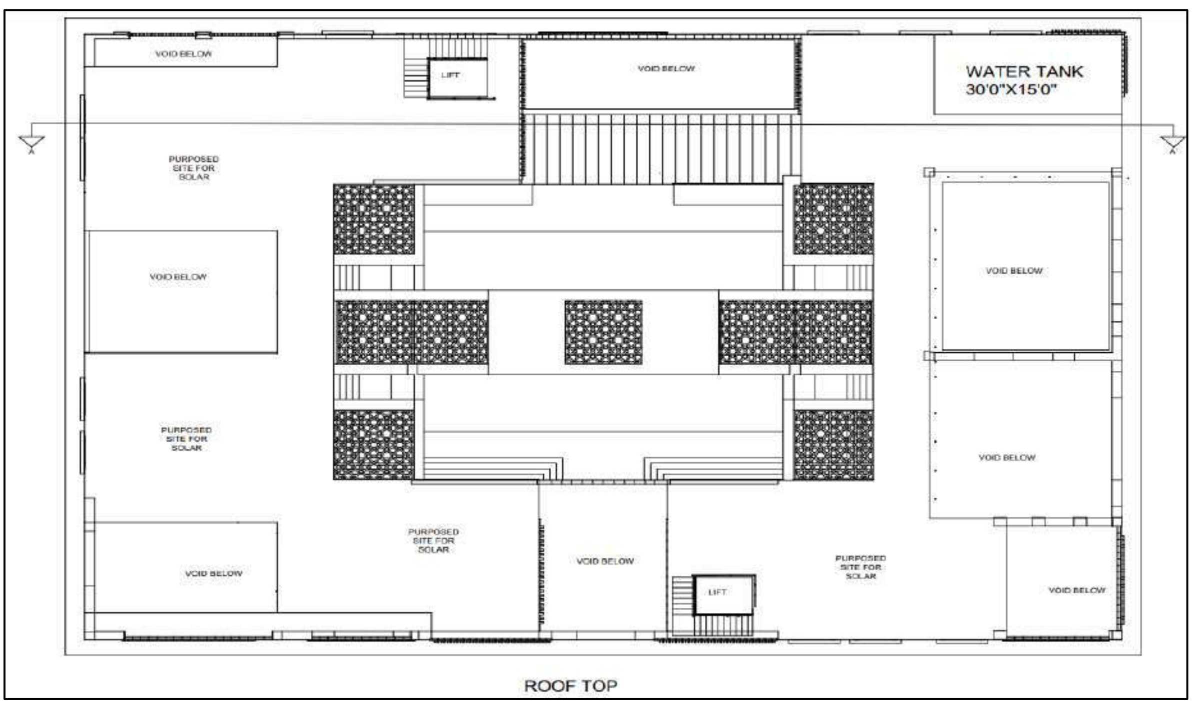


Figure 4.13: University building top view - Roof top *(AutoCad 2022)*

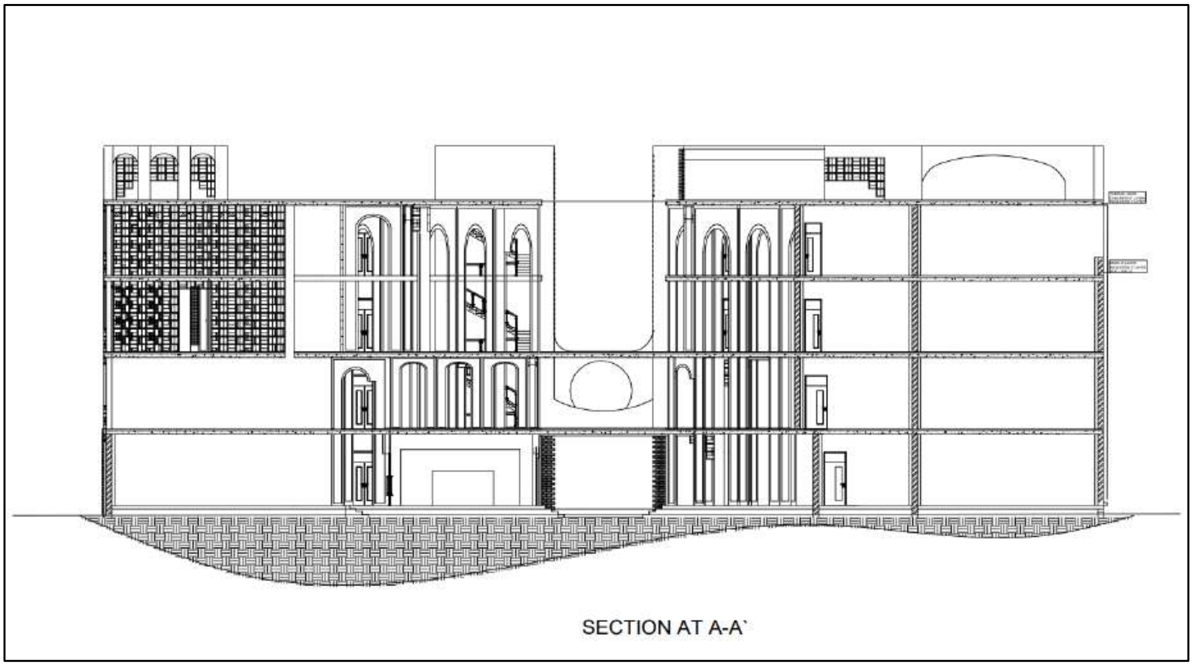


Figure 4.14: University building section *(AutoCad 2022)*

#### 4.1.2.2 Hostel Plans and Section

The provided figures outline the plans and section specifically dedicated to the hostel facilities within the university.

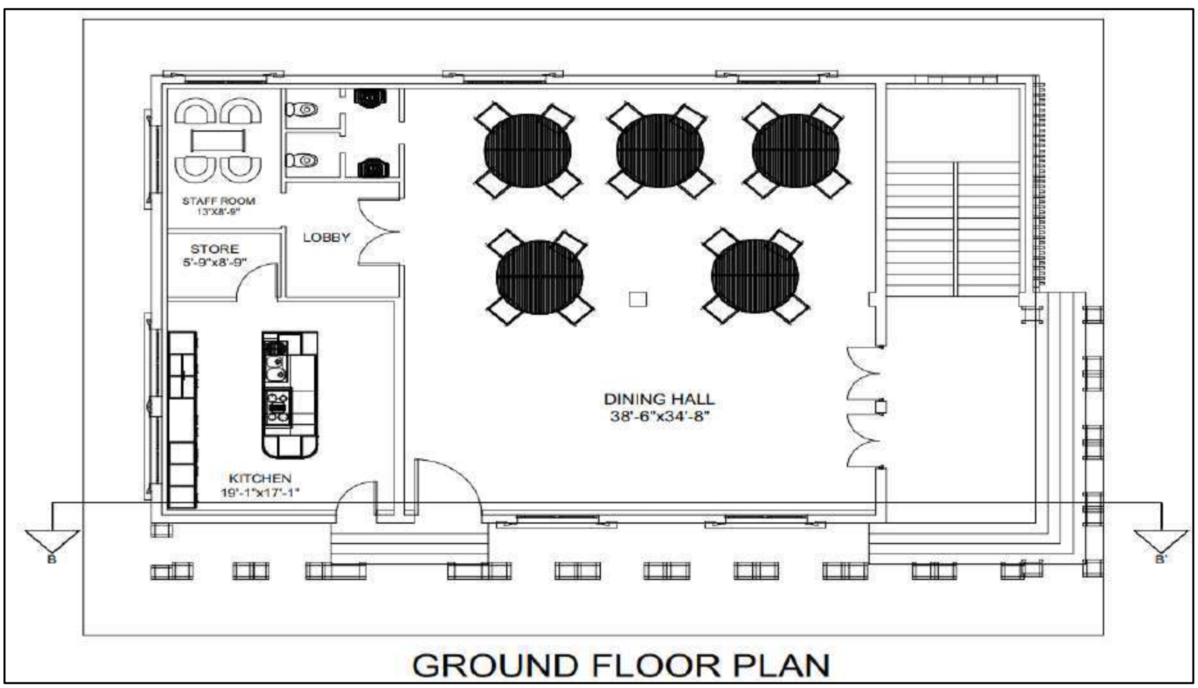


Figure 4.15: Hostel top view - Ground floor *(AutoCad 2022)*

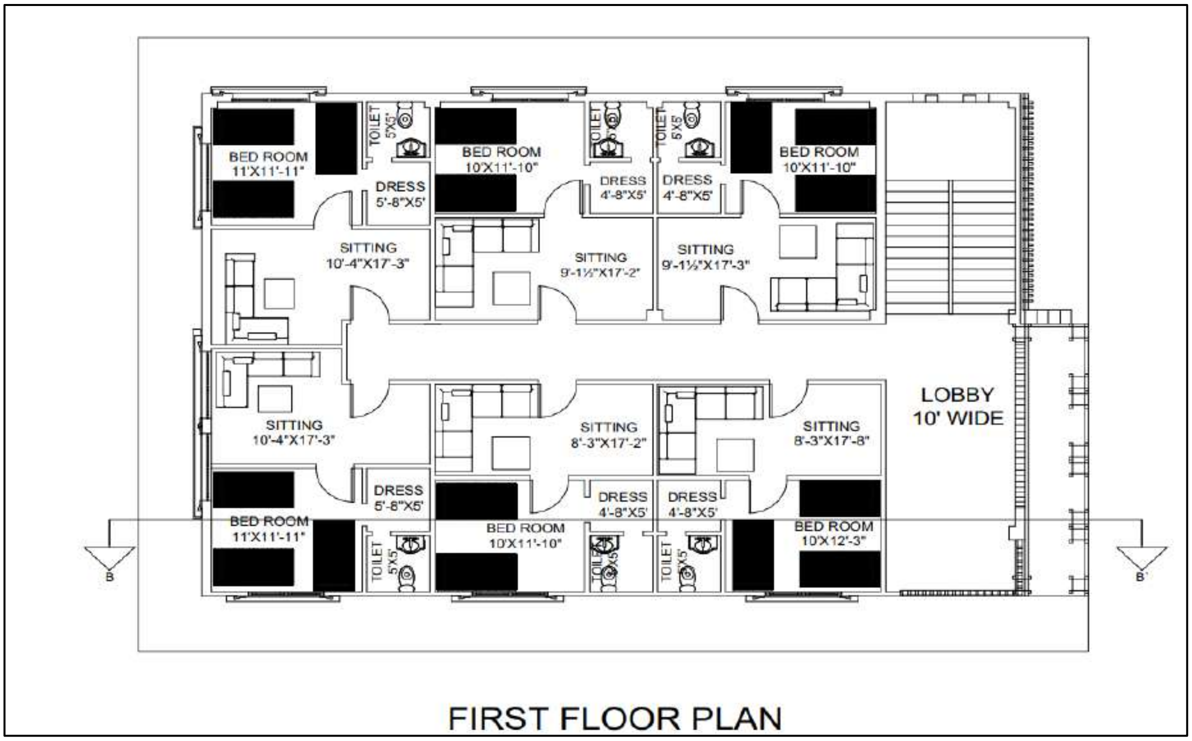


Figure 4.16: Hostel top view - First floor *(AutoCad 2022)*

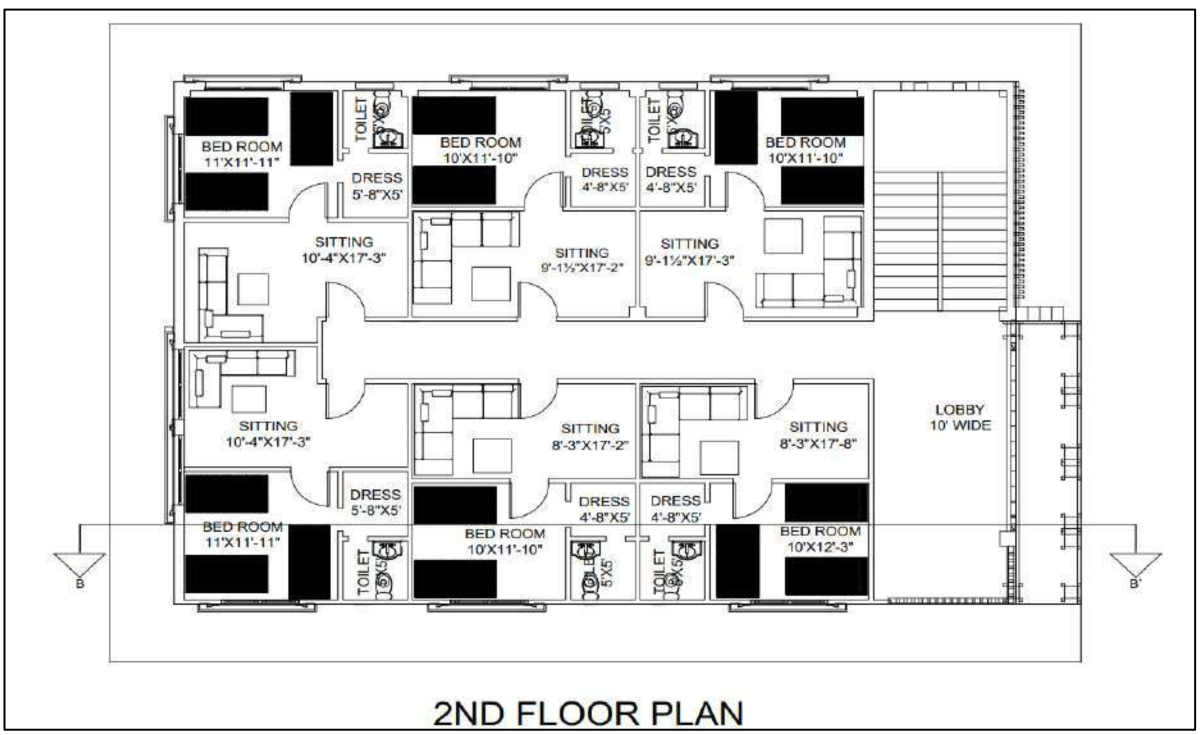


Figure 4.17: Hostel top view - Second floor *(AutoCad 2022)*

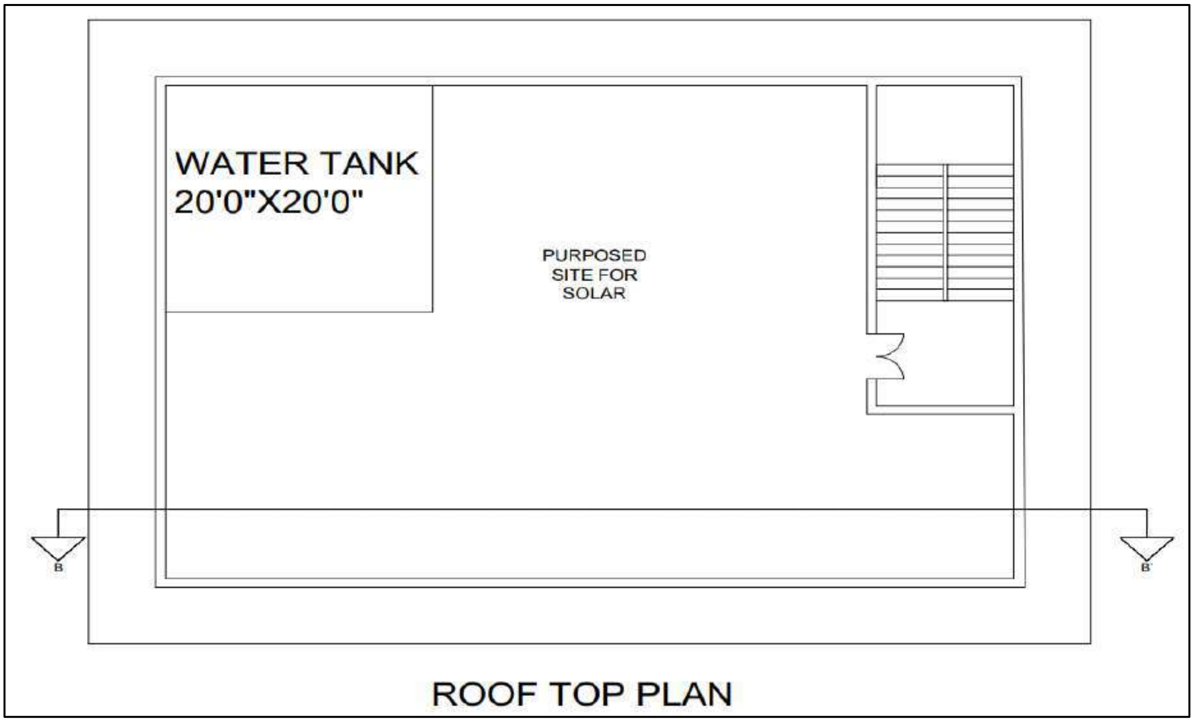


Figure 4.18: Hostel top view - Roof top *(AutoCad 2022)*

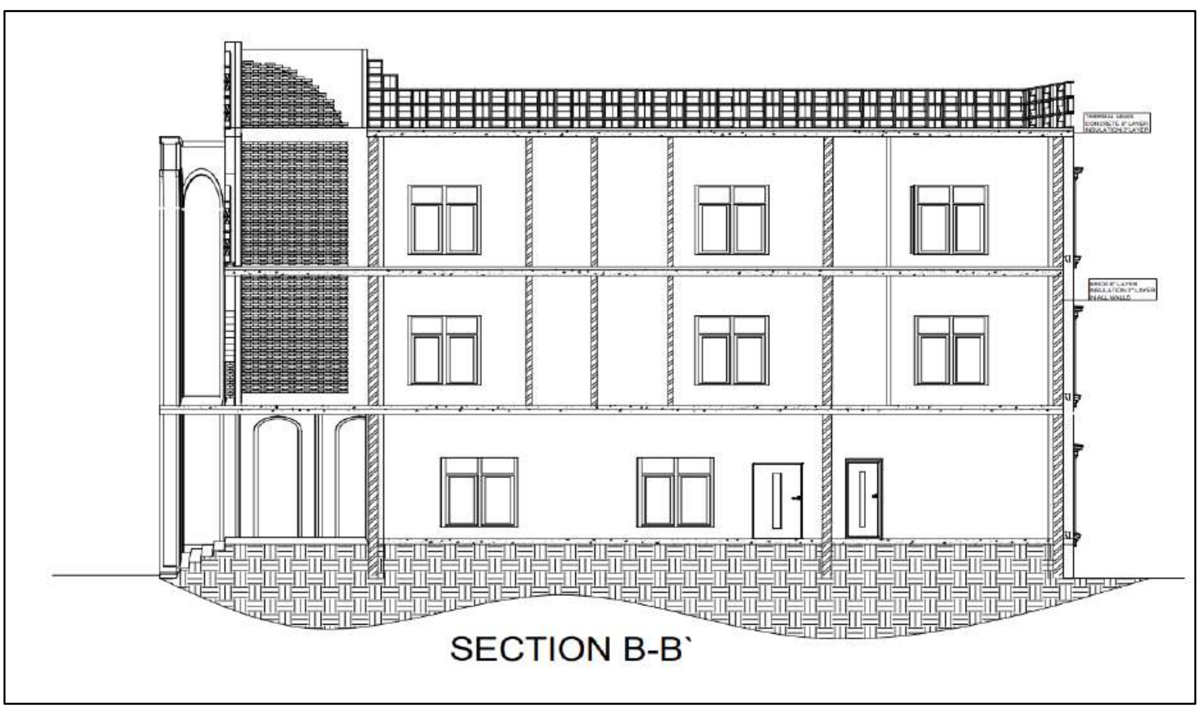


Figure 4.19: Hostel section *(AutoCad 2022)*

**Multi purpose hall Section**

The figure 4.20 showcases the detailed section of the multi purpose hall, offering a comprehensive view of its design and layout.

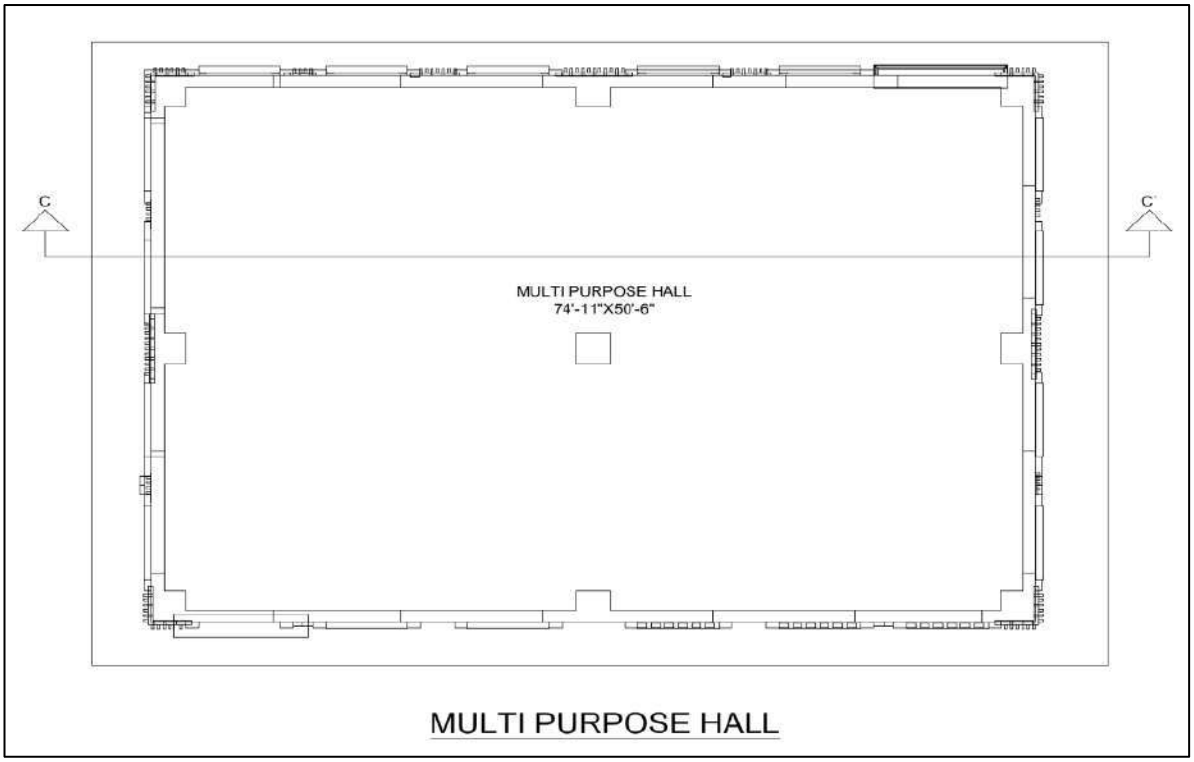


Figure 4.20: Multi purpose hall section *(AutoCad 2022)*

### 4.1.3 Building Particulars

The building's specifications have been selected to comply with net zero energy building (NZEB) requirements. The building's entire plinth area, including the hostel and multi purpose hall is 81791 square feet and its total roof area is 20110 square feet. There are 47 classrooms available to the institution. There are around 1500 active students at the institution, and there are 60 students in each classroom.

Water resources and certain building details have been identified.

Table 4.2: Building Particulars

| | |
|---|---|
| Total building plinth area | 7601.3 sq. m. (or) 81791 sq. ft. |
| Total roof area | 1886 sq.m or 20110 sq.ft |
| No. of classrooms | 47 Rooms |
| Total no. of students | 1440 ≈ 1500 (approximately) |
| Projectors | 40 |
| Water pumps | 3 |
| Digital clocks | 3 |
| Exhaust fans | 16 |
| Wifi routers | 4 |
| Inkjet printer | 2 |
| Phone charger | 240 |
| Total fans | 188 |
| Total lights | 52 |

**Water Resources**

The water resources for the designed net zero energy building are depicted below:

No. of classrooms: 47

No. of operational classrooms (Excluding examination halls): 24

No. of students per class room: 60

Total no. of students: 1440 ≈ 1500 (approximately)

Water usage (Including water for drinking, flushing, washing): 45 Litres / head / day (IS 1172:1993)

Water Demand: 67500 Litres /capita / day

Annual Water demand (Approximately, excluding non working days): 12,352.500L

## 4.2 Incorporation of Industrial Sludge

Figure 4.21 shows the possibilities for using dried sludge and rice husk ash to create new, lightweight blocks (block wall mixture). The mechanical property findings reveal that the bricks containing 40% by weight of rice husk heated to 1100°C display the high strength necessary for lightweight blocks to be used in future ZEB structures. The usual combination of cement, sand, and aggregate in the proportions of 1:3:6 is represented by the remaining portion (60%) of the pie chart (O.A. Johnson et al., 2014).

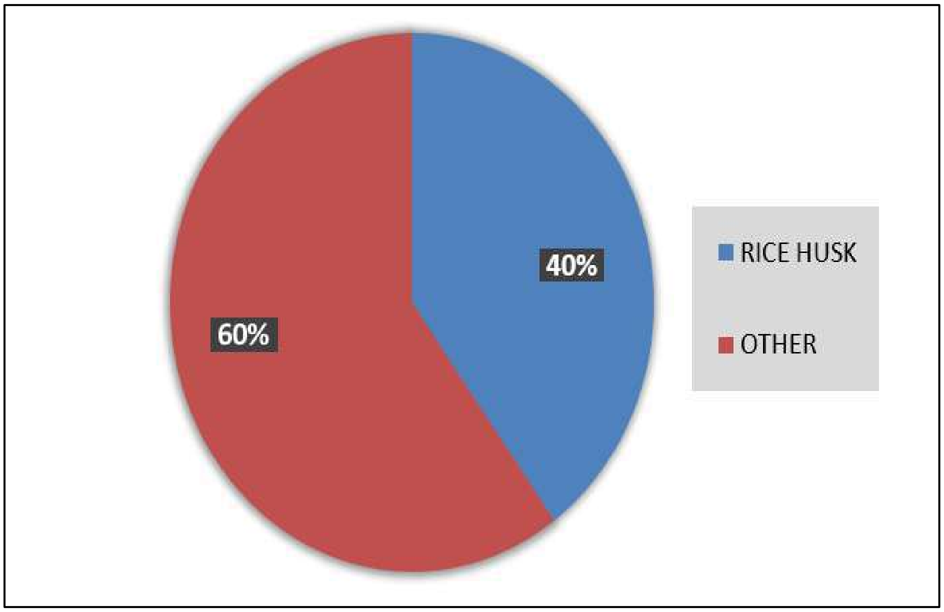


Figure 4.21: Depiction of block wall mixture

The usage potential of digested and dewatered sludge in the manufacture of cement is examined in Figure 4.22. Cement was replaced with sewage sludge ash up to 30% by weight. Similar to this, the typical cement mixture (60%) can have up to 10% of pulverised sludge ash added to it. This cement's 28-day compressive strength was comparable to that of regular concrete.

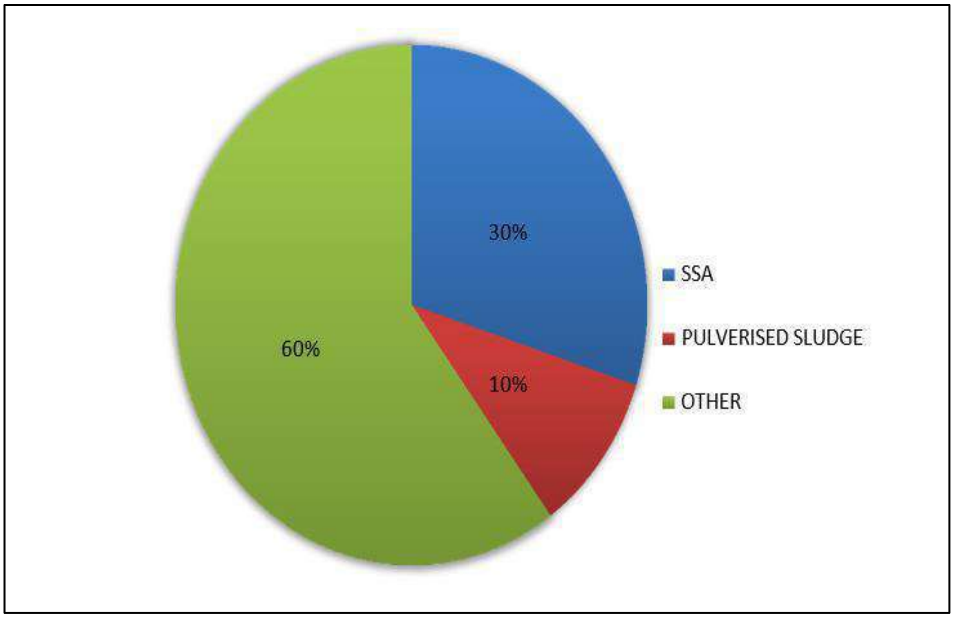


Figure 4.22: Depiction of cement mixture

The potential inclusion of dry sludge in concrete mix is shown in Figure 4.23. The nominal composition of cement, sand, and aggregate was 1:2:3 with dry sludge added as fine sand at 9% of the total.

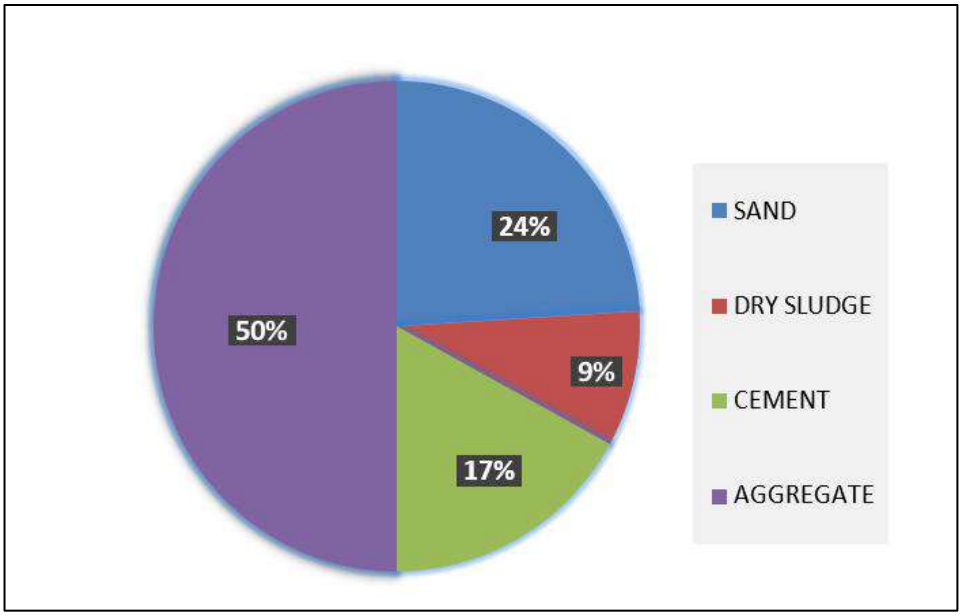


Figure 4.23: Depiction of concrete mixture

In Figure 4.24, 50% sludge ash and 5% limestone product sludge are shown as fine dust that may be combined directly with the remaining 45% of the ingredients in ceramic paste. This mix demonstrated normal levels of strength and acid resistance.

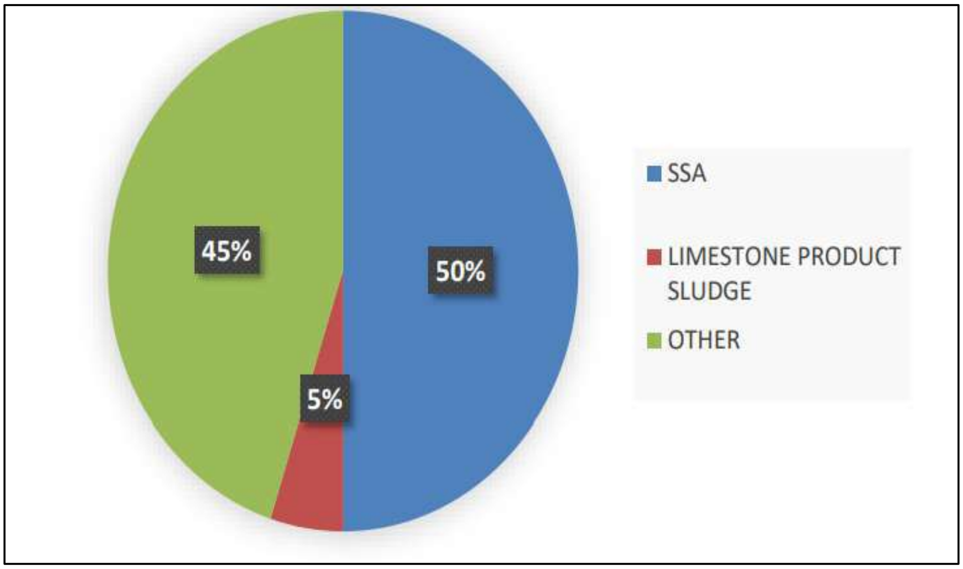


Figure 4.24: Depiction of ceramic and glasses

According to Figure 4.25, sewage sludge can replace clay in a tile body to a maximum of 10% of the typical 90% clay combination.

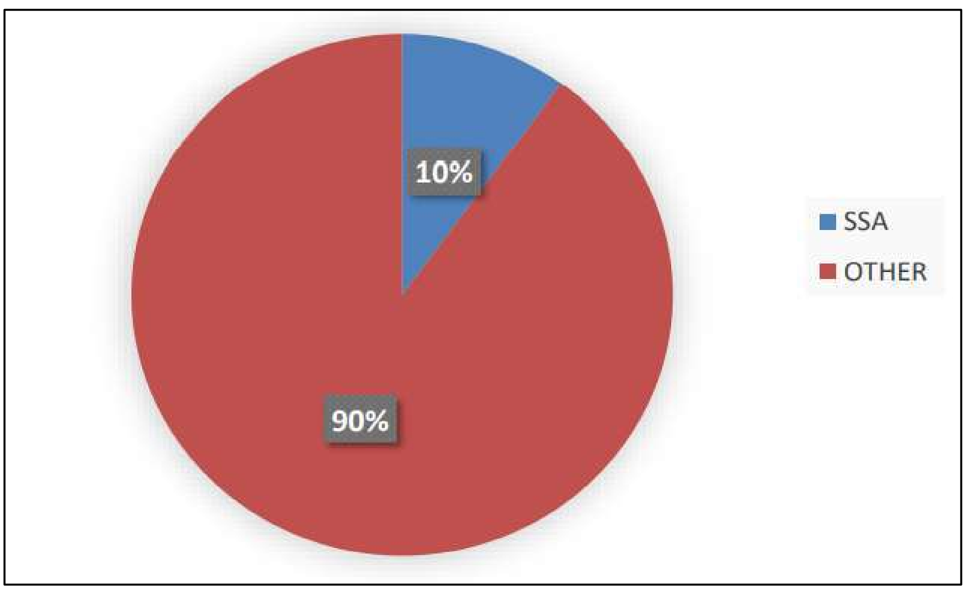


Figure 4.25: Depiction of tile mixture

## 4.3 Computer Simulation of the Net Zero Energy Educational Building

The net zero energy educational building has been modelled in SketchUp Pro 2020 software and 3d renders have been developed in Lumion 10 software.

### 4.3.1 Master Plan

The Figure 4.26 illustrates the master plan of the net zero energy educational building modelled in Sketchup pro 2020. The structure houses the main university building as well as a hostel and a multi purpose hall. The building has been orientated towards South to maximise solar energy absorption by the solar panels installed and to provide optimum ventilation and light to decrease use of artificial lighting and ventilation systems. The building's thermal performance is improved by the inclusion of open green areas throughout, which also displays significant energy reduction, extends the lifespan of the roof and helps cities adapt to a warming world.


Figure 4.26: Depiction of site's master plan for the proposed building *(SketchUp Pro 2020)*

### 4.3.2 3D Views of the Building Incorporated with NZEB Features

The different views of the net zero energy educational building along with multi purpose hall and hostel are depicted below.

Figure 4.27: 3D view showing university building, multi purpose hall & parking *(SketchUp Pro 2020)*

Figure 4.28: 3D view showing university building *(SketchUp Pro 2020)*

Figure 4.29: 3D views showing building entrance

*(SketchUp Pro 2020)*

Figure 4.30: 3D views showing multi purpose hall

*(SketchUp Pro 2020)*

Figure 4.31: 3D views showing hostel

*(SketchUp Pro 2020)*

Figure 4.32: 3D view of classroom showing LED lights & BLDC fans

*(SketchUp Pro 2020)*

### 4.3.3 Energy Efficient Features of the Net Zero Energy Educational Building

The following essential energy efficient features of a NZEB are installed in the building using SketchUp Pro 2020 software and 3D renders are created in Lumion10 software.

- Machine room
- Thermal mass bricks
- Thermal Mass Flooring
- Double Glazed Windows
- Exterior Rain Drip Guard over windows
- Rain Water Harvesting system
- Grey Water Treatment system
- BLDC fans
- LED Lights
- Solar Panels
- Parking Lot solar canopy
- Open Green spaces
- Fly Ash Concrete Blocks
- Piezo Electric Strips
- Study Courtyard
- Wooden Floor Seating
- Low volatile organic paint walls etc

**Machine Room**

The machine room consists of a filtration plant (blue) which filters the water and stores it in the underground tank. Above the underground tank, the motor (green) is provided in the machine room which carries water from the underground tank to the overhead tank where it can be used as an alternative water source, minimizing water consumption in the building.


Figure 4.33: 3D view showing machine room *(SketchUp Pro 2020)*

Figure 4.34:Inside view of machine room *(SketchUp Pro 2020)*

**Rain Water Harvesting System**

A rainwater harvesting system is installed in the structure to collect and utilize rainwater, however only 25 to 30 percent of the roof space is accessible for harvesting because the remaining space is taken up by solar panels. Only during rainy nights does primary absorption occur, while surface runoff occurs throughout the day from the remaining area.

The figure 4.35 depicts the open water tank provided in the building to collect rain water while figure 4.36 depicts the rain water harvesting system implemented in the building.

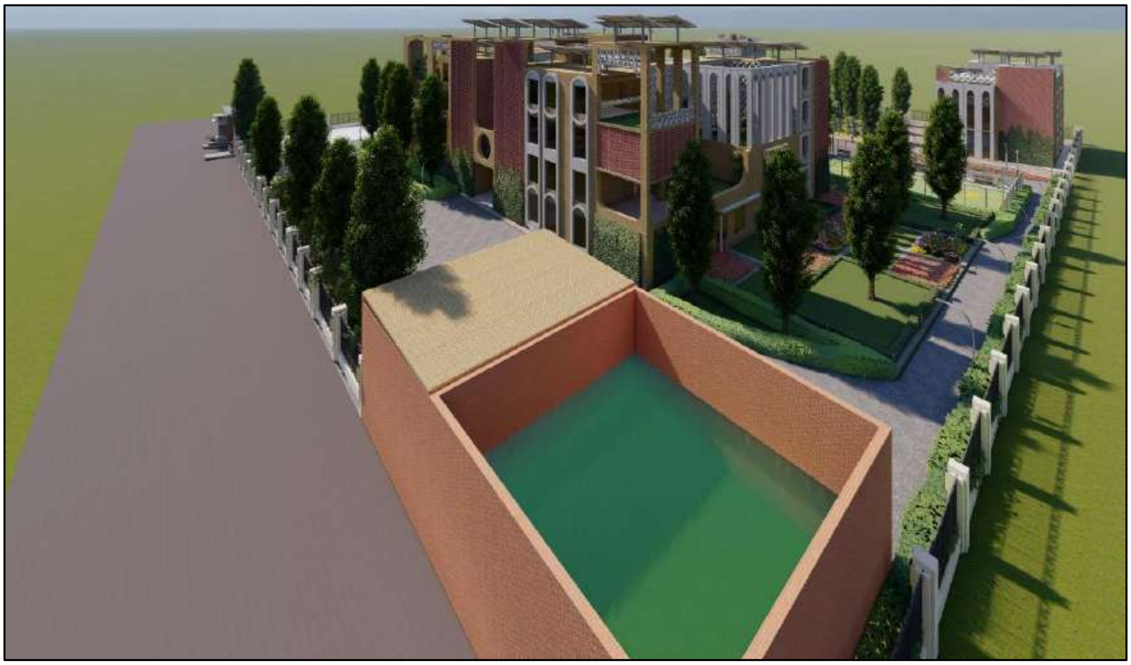

Figure 4.35: Open water tank to collect rain water *(SketchUp Pro 2020)*

**Working of Rain Water Harvesting System**

The drain pipes on a building's roof are used to collect rainwater. The rainwater that has been collected is filtered to make it safe for consumption. The harvested rainwater is then stored in the overhead tank, where it may be utilised for a variety of purposes, including flushing toilets, washing cars, gardening, livestock, irrigation, etc as depicted in figure 4.36.

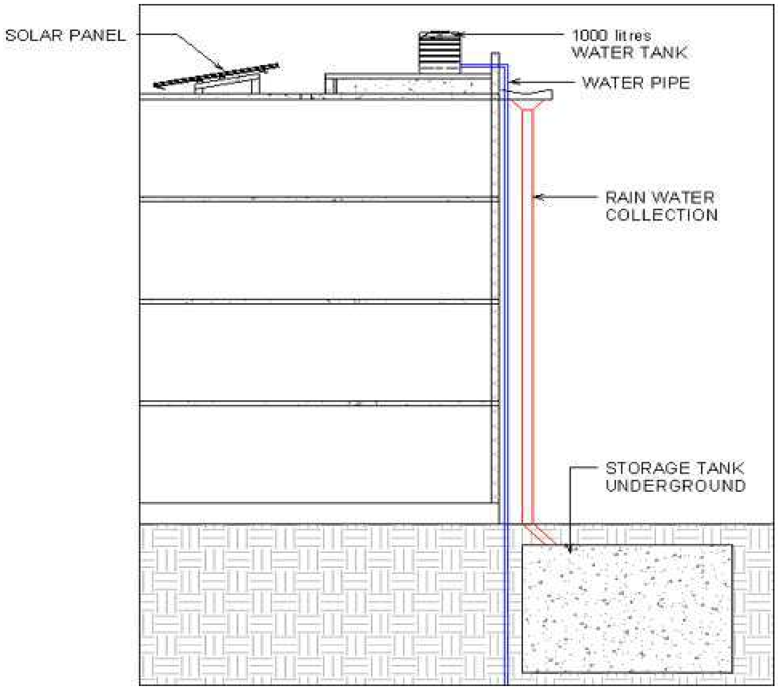


Figure 4.36: Sectional elevation showing rain water harvesting system *(SketchUp Pro 2020)*

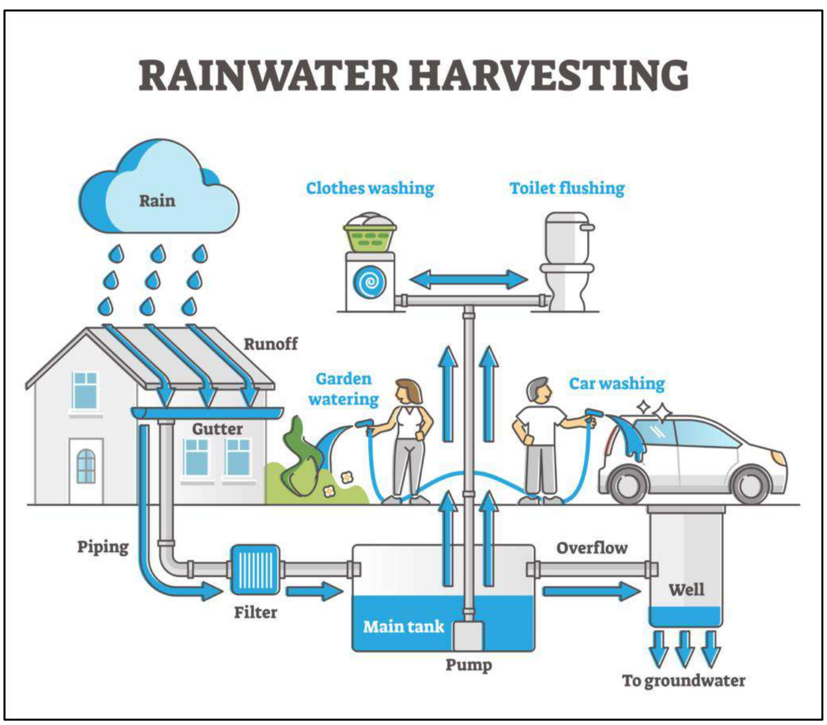


Figure 4.37: Working of rain water harvesting system *(SA Clean Water)*

**Grey Water Treatment System**

The building is provided with a grey water treatment system. Grey water systems is installed and the building's grey water is processed in a separate room that is built into the west side of the building. There are two 175-gallon storage tanks in the room. They are created with the use of Loadable families in SketchUp Pro 2020. The water is used for watering of plants in the atrium, flushing of toilets, and other landscaping purposes.

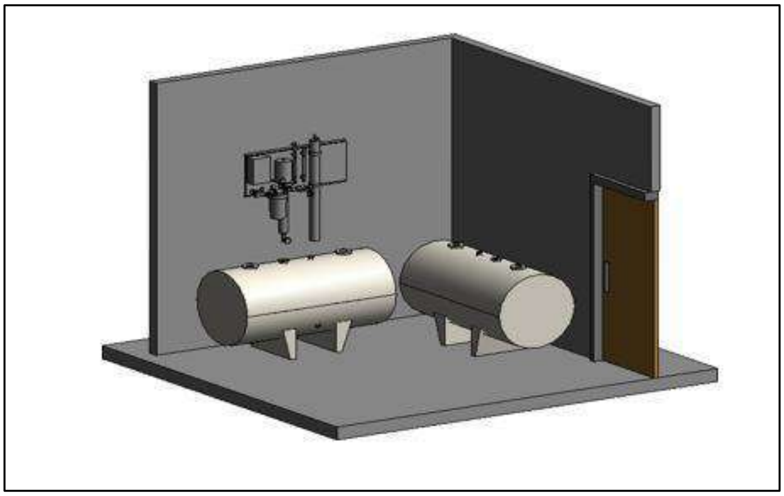

Figure 4.38: 3D interior view of grey water harvesting room *(SketchUp Pro 2020)*

The figure 4.39 depicts how a grey water treatment system works in a net zero energy (NZE) building.

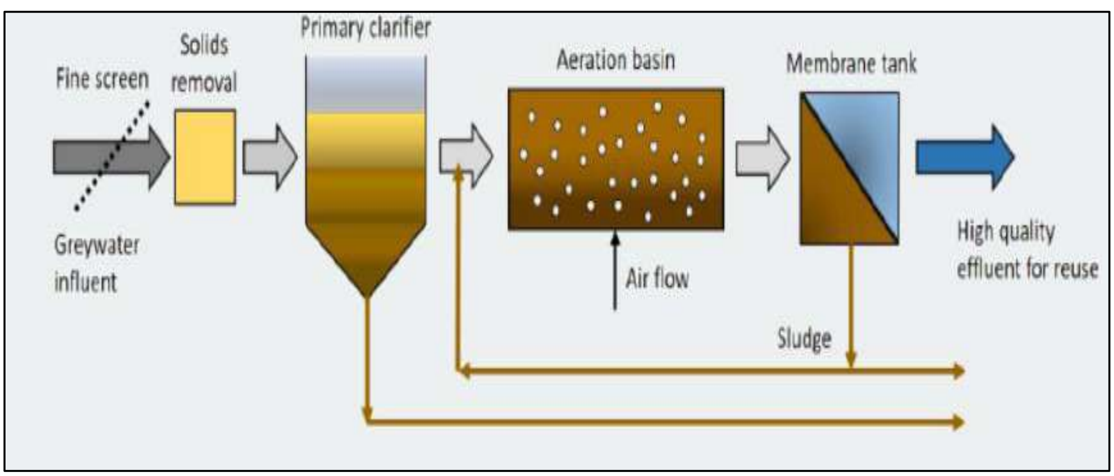


Figure 4.39: Working of the grey water treatment system *(RBIS – India Information)*

**Thermal Mass Bricks (Brick Jali)**

Thermal mass bricks with red colored brick jali are used throughout the building. In the summer, these bricks absorb heat, bringing down the inside temperature. Thermal mass bricks act as a warmer in winter by absorbing radiant heat from the sun coming in via windows. The heat is then gradually released, reducing the demand for heating. Brick jalis enable light and air while minimizing sunlight and rain and also offer passive ventilation for cooling.

The walls are covered with creeper plants because their leaves reduce pollutants and act as insulation, keeping buildings cool in the summer and warm in the winter.

The figure 4.40 depicts thermal mass bricks with brick jali and creeper plants used in the walls of the building.

Figure 4.40: 3D view showing walls with thermal mass bricks and creeper plants

*(SketchUp Pro 2020)*

**Thermal Mass Floors**

The figure 4.41 shows the incorporation of thermal mass flooring in SketchUp Pro 2020. These concrete slab floors will significantly minimise the amount of sun's radiation that is absorbed into the floor, and less heat will be released later, when it is cooler.

Figure 4.41: Thermal mass flooring depicted in SketchUp *(SketchUp Pro 2020)*

**Working of thermal Mass**

Figure 4.42 shows how thermal mass maintains temperature in zero-energy buildings.

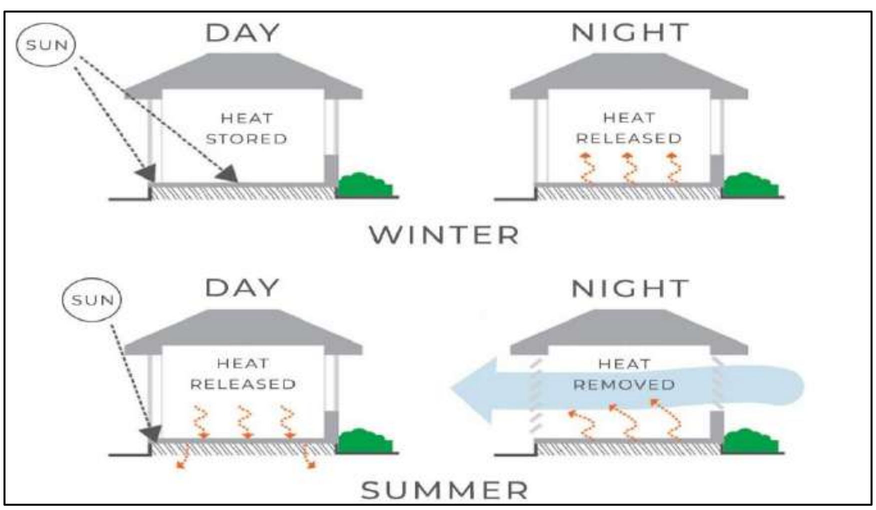


Figure 4.42: Working of thermal mass in buildings *(The Constructor)*

**Solar Panels**

To meet the building's energy requirements, 60 solar panels of 450 watt capacity are installed using Lodable Family on SketchUp Pro 2020. They contain additional storage features that allow for use at night and in the winter, when solar energy isn't as readily available as it is in the summer. In order to get the most direct sunshine, the solar panels are oriented towards the south.

Figure 4.43: 3D views showing solar panels on building roofs *(SketchUp Pro 2020)*

**Working of Solar Panels**

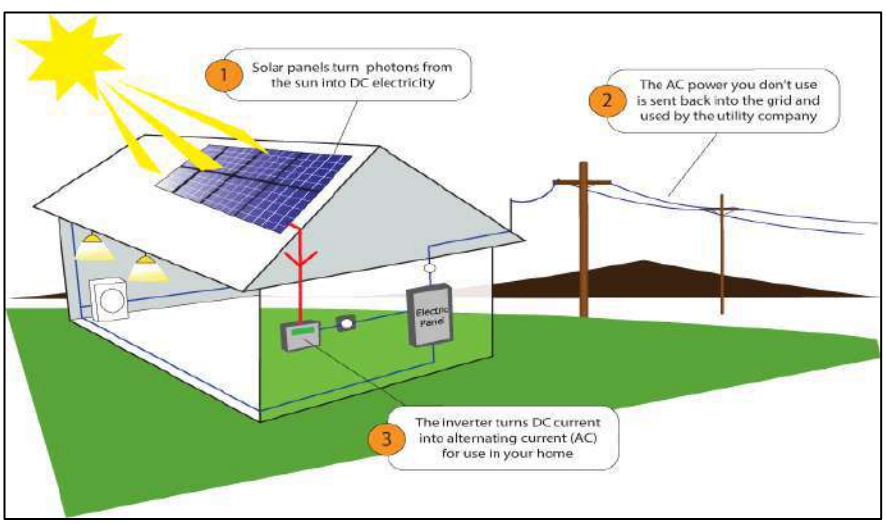


Figure 4.44: Working of solar panels *(Alpha Solar)*

**Parking Lot Solar Canopy**

Solar Polars of 450 watt capacity oriented towards South are installed over the entire parking lot to produce on-site energy that can significantly lower energy bills, creates shadier spaces and cut $CO_2$ emissions.

Figure 4.45: Solar canopy over parking lot *(SketchUp Pro 2020)*

**Double Glazed Windows**

All of the building's windows are double-glazed because they effectively minimise the passage of heat, the insulating gas in the space between the panels of such windows stops heat from passing through. This increases sustainability. These windows help to minimise energy consumption by keeping the building warmer in the winter and cooler in the summer.

The windows are 5 feet in length and 5 feet in height. Small aluminium panels and double glazing are used to create these windows. This is made possible on the SketchUp software by using the architectural window element and altering the type of window.

The double-glazed windows installed in the net zero energy building are shown in figure 4.46.

Figure 4.46: Double glazed windows installed *(SketchUp Pro 2020)*

Double glazing & Low U value (Heat transfer co-efficient) further support NZEB by:

- Storing and using natural heat captured during the summer.
- Less energy is used to heat or cool a room.
- In comparison to other models, they are extremely resistant to breaking and provide tight sealing.
- When there are more units, there is less noise, and sound proof rooms increase the amount of noise insulation.

**Working of Double Glazed Windows**

As illustrated in figure 4.47, double glazed windows employ two panes of glass separated by a layer of trapped argon gas to keep the structure more energy efficient. Since argon gas conducts heat poorly (only 67% of that of air), warm air is kept within buildings, increasing energy efficiency.

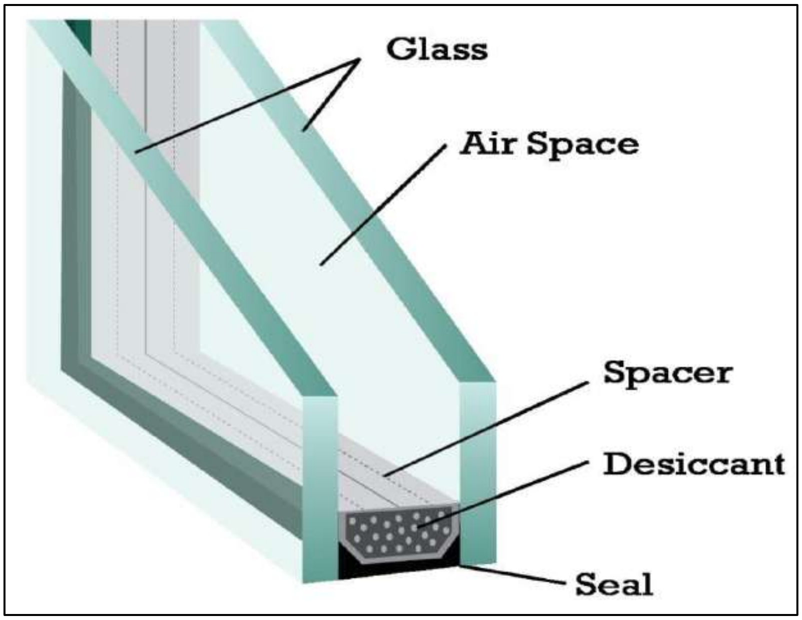


Figure 4.47: Double glazed windows *(MODA Home UPVC)*

**Exterior Rain Drip Guard over Windows**

Windows have exterior rain drip guards installed above them at sufficient depth that will protect them from water damage. Rainwater is collected in these guards and sent by pipe to the underground tank.

Figure 4.48: Exterior rain drip guard over windows *(SketchUp Pro 2020)*

**Central Courtyard with Fly Ash Concrete Columns and Thermal Mass Bricks**

The building is provided with a central courtyard which makes the building cooler. Fly ash concrete is used in the columns where thermal mass bricks are used in the walls. Compared to conventional concrete, fly ash concrete consumes roughly 85% less energy, emits less $CO_2$ and is more cost-effective.

Figure 4.49: Central courtyard with fly ash concrete columns *(SketchUp Pro 2020)*

Figure 4.50: Central courtyard with thermal mass bricks *(SketchUp Pro 2020)*

**LIGHT EMITTING DIODE (LED) Lights**

LED light bulbs are installed in the classroom. These lights are installed using Loadable and System Family on SketchUp Pro 2020. The most energy-efficient and quickly evolving lighting technology available today is LED. Compared to a conventional bulb with the same light output, these lights can save up to 90% energy.

Figure 4.51: 3D view of classroom showingh LED lights *(SketchUp Pro 2020)*

The figure 4.52 illustrates the differences between different lighting equipments.

ENERGY EFFICIENT LIGHT BULBS VS REGULAR LIGHT BULBS

| ENERGY EFFICIENCY | Light Emitting Diodes (LEDs) | Compact Fluorescent Lamps (CFLs) | Incandescent Light Bulbs |
|---|---|---|---|
| Electricity Used | 6-8 Watt | 13-15 Watt | 60 Watt |
| Carbon Dioxide Emissions | 451 £/year | 1051 £/year | 4500 £/year |
| Durability | Very Durable | Not Very Durable | Not Very Durable |
| Heat Emitted | 3.4 btu / hr | 30 btu / hr | 85 btu / hr |

Figure 4.52: Comparision of conventional, CFL, LED equipment *(Progressive Materials)*

**Brushless Direct Current (BLDC) Fans**

Brushless Direct Current electric motor driven fans are installed. In terms of durability, life expectancy, and technical advancement, BLDC fans are more reliable than conventional ceiling fans. These fans can save power usage by up to 65% when compared to a typical induction fan.

Figure 4.53: 3D view of classroom showing BLDC fans *(SketchUp Pro 2020)*

The figure 4.54 shows the comparision of BLDC fan with a regular fan.


Figure 4.54: Comparision of BLDC fan with a regular fan *(CAG)*

**Study Courtyards**

Green roofs are provided at every floor of the building which can be used as study courtyards incase of electricity outage and heat. Green roofs offer shade, cool the surrounding air and the roof surface by absorbing heat from the atmosphere.

Figure 4.55: 3D view showing study courtyard *(SketchUp Pro 2020)*

**Low VOC Paint**

The walls and columns throughout the building are painted using low volatile organic compound (VOC) paints. These paints have the least quantity of volatile organic compounds which improves indoor air quality and protects the ozone layer. They have a mild odour and are less energic.

Figure 4.56: Walls and columns are painted using low VOC paint *(SketchUp Pro 2020)*

**Piezoelectric Strips**

Piezoelectric strips are provided at the entrance of the building, driving track and parking lot. These strips produce electricity when pressed by cars and pedestrians. The working of such strips is depicted in the reference figure.

Figure 4.57: 3D view showing piezoelectric strips at building entrance

*(SketchUp Pro 2020)*

**Working of Piezoelectric Strips**

1. Normally, the charges in a piezoelectric strip are exactly balanced, even if they're not symmetrically arranged.
2. The effects of these charges precisely cancel each other out, leaving the strip with no net charge.
3. However, the charges become unbalanced when the strips are compressed by vehicles or pedestrians.
4. As a result, net positive and negative charges now appear on the opposing faces of the strip since the effects of the charges no longer cancel one another out. Squeezing the strip creates a voltage across its opposing face which generates electricity as depicted in figure.

The operation of piezoelectric strips is shown in figure 4.58.

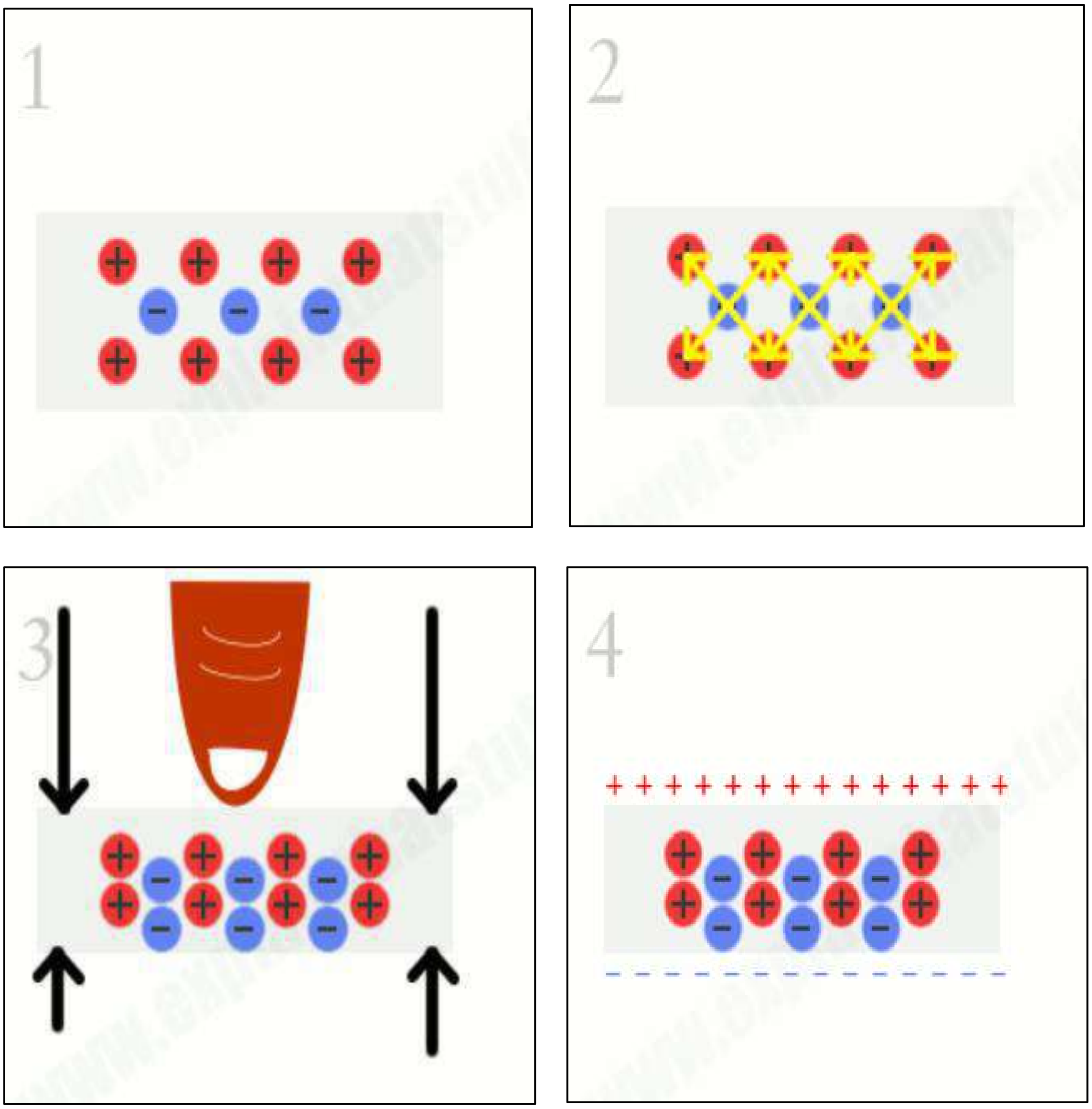

Figure 4.58: Working of piezoelectric strips

*(Explain That Stuff)*

**Open Green Spaces**

In order to increase the building's thermal performance, which is improved by the building's large energy savings, extended roof lifespan and ease of urban adaption to a warmer environment, open green spaces are provided everywhere throughout the building.

Figure 4.59: 3D views showing open green spaces

*(SketchUp Pro 2020)*

**Wooden Floor Seating**

The building is provided with wooden floor seating as such seats are simple and meant to accommodate a large number of students. Such seats can be used to sit, eat and entertain.

Figure 4.60: 3D view showing wooden floor seats (SketchUp Pro 2020)

**Playground**

The building is also provided with a playground for different sport activities.

Figure 4.61: 3D view showing playground *(SketchUp Pro 2020)*

### 4.3.4 3D Lumion Renders

The 3D renders of the university building, muti purpose hall and hostel developed in Lumion 10 software are depicted below:

#### 4.3.4.1 University Building Renders

The 3D renders of different views of the building are depicted below.

Figure 4.62: University building 3D renders - Front views *(Lumion 10)*

Figure 4.63: University renders 3D renders - Side views *(Lumion 10)*

Figure 4.64: University buiding 3D render - Back view *(Lumion 10)*

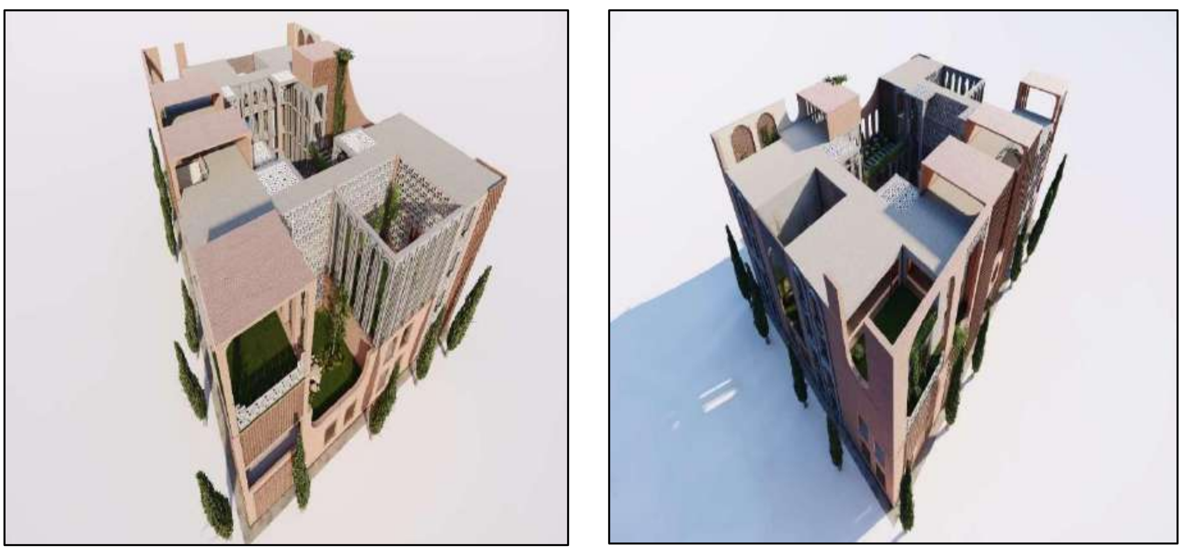

Figure 4.65: University building 3D renders - Top views *(Lumion 10)*

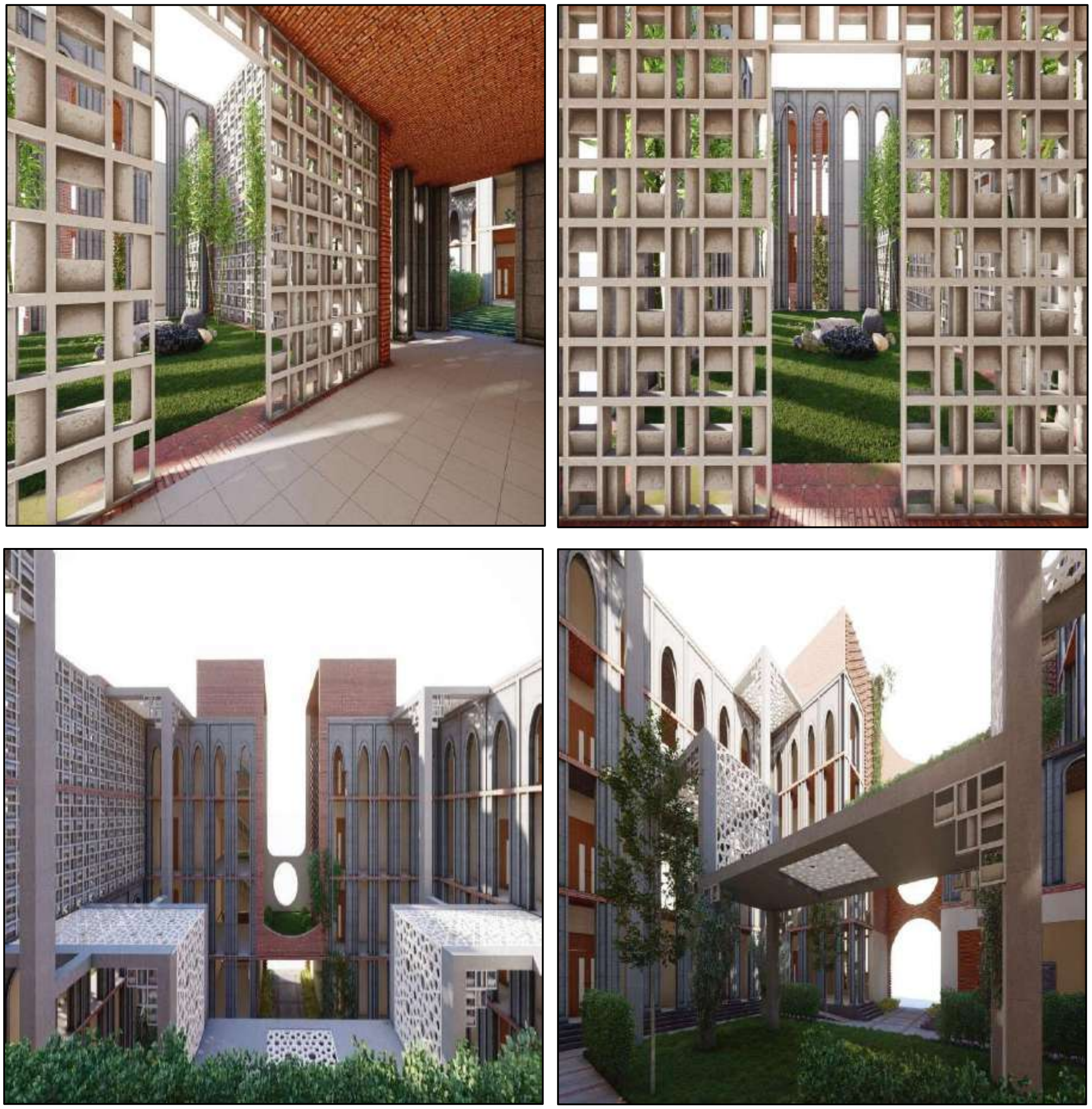

Figure 4.66: University building 3D renders - Inside views

*(Lumion 10)*

#### 4.3.4.2 Multi Purpose Hall Renders

The 3D renders of the multi purpose hall are illustrated in figures below.

Figure 4.67: Multi purpose hall 3D render - Front view *(Lumion 10)*

Figure 4.68: Multi purpose hall 3D render - Side view (Lumion 10)

#### 4.3.4.3 Hostel Renders

The 3D renders of the hostel from different views are depicted below.


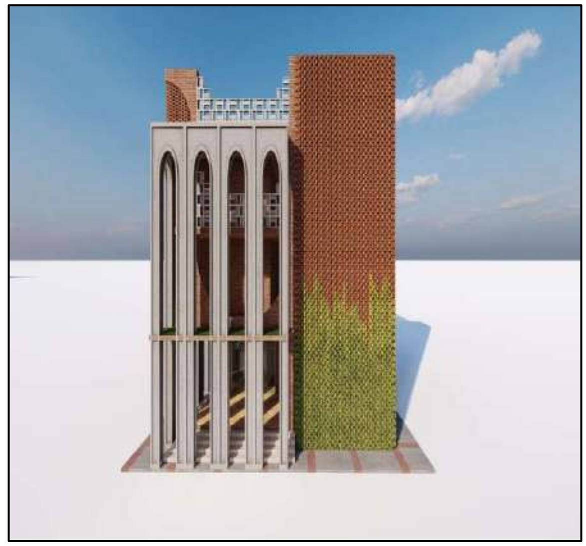

Figure 4.69: Hostel 3D renders - Front views *(Lumion 10)*

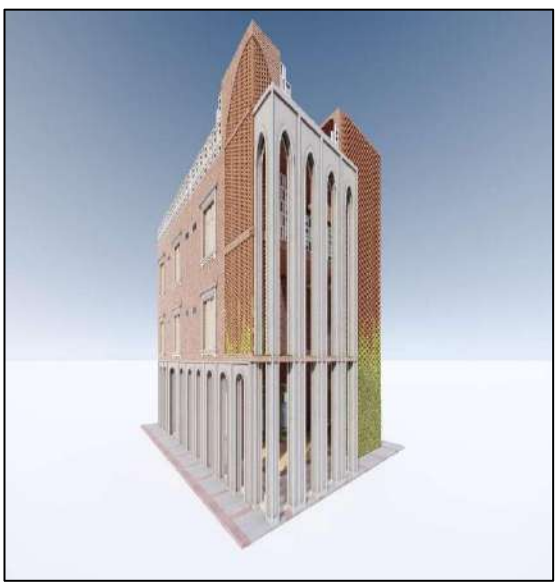


Figure 4.70: Hostel 3D renders - Side views *(Lumion 10)*

## 4.4 Environmental Audit

Using Autodesk Green Building Studio, an environmental audit is conducted to evaluate the building's energy usage and to contrast traditional and energy-saving practises.

The energy consumption of the employed energy efficient alternatives is shown in table 4.3, although being less in number than the traditional appliances, they are equally efficient. In the computation above, the individual consumption of each "energy-efficient" equipment in relation to the expected usage has been noted. In light of this, we deduce that the building's energy-efficient replacements use around 26.5 KW of energy each day and 582 KW over the course of 22 days (working days in a month).

Table 4.3: Energy consumption by energy saving appliances

| APPLIANCES | QTY | For Each item in watts | Output wattage | Usage HRS | WATT HRS PER DAY |
|---|---|---|---|---|---|
| PROJECTORS | 40 | 270 | 10800 | 3 | 32400 |
| WATER PUMPS | 3 | 800 | 2400 | 3 | 7200 |
| DIGITAL CLOCKS | 3 | 5 | 15 | 24 | 360 |
| EXHAUST FANS | 16 | 12 | 192 | 2 | 384 |
| WIFI ROUTER | 4 | 20 | 80 | 12 | 960 |
| INKJET PRINTER | 2 | 50 | 100 | 3 | 300 |
| PHONE CHARGER | 240 | 5 | 1200 | 4 | 4800 |
| | | | 14787 | 51 | 46404 |
| | | Total Fans in the Building | | | |
| GROUND FLOOR | 44 | 40 | 1760 | 9 | 15840 |
| FIRST FLOOR PLAN | 44 | 40 | 1760 | 9 | 15840 |
| SECOND FLOOR | 50 | 40 | 2000 | 9 | 18000 |
| THIRD FLOOR | 50 | 40 | 2000 | 9 | 18000 |
| | 188 | | 7520 | 36 | 67680 |
| | | LIGHTS PRESENT ON A SINGLE FLOOR | | | |
| CLASS ROOM 1- 10 | 30 | 20 | 600 | 3 | 1800 |
| RECEPTION + LOBBY | 6 | 20 | 120 | 7 | 840 |
| STAFF ROOM | 2 | 20 | 40 | 5 | 200 |
| CORRIDOR | 14 | 20 | 280 | 7 | 1960 |
| | 52 | | 1040 | 22 | 4800 |
| TOTAL WATTS REQ. | IN KILO WATTS | | | | |
| 26467 | 26.467 | | | | |
| ENERGY REQUIRED | | | | | |
| PER DAY = 26.5KW | | | | | |
| FOR 22 DAYS = 582KW | | | | | |

Table 4.4 now provides an analysis for the scenario when the same number of conventional appliances are utilised instead of energy efficient ones. In the computation above, the individual consumption of each "conventional" appliance in relation to the expected usage has been noted. The number of appliances in use here is the same as their energy-efficient equivalents. So, we get to the conclusion that conventional/traditional equipments, if employed in the building, use about 45 KW of energy each day.

Table 4.4: Energy consumption by traditional applianmces

| APPLIANCES | QTY | For Each item in watts | Output wattage | Usage HRS | WATT HRS PER DAY |
|---|---|---|---|---|---|
| PROJECTORS | 40 | 350 | 14000 | 2 | 28000 |
| WATER PUMPS | 3 | 965 | 2895 | 3 | 8685 |
| DIGITAL CLOCKS | 3 | 5 | 15 | 12 | 180 |
| EXHAUST FANS | 16 | 50 | 800 | 2 | 1600 |
| WIFI ROUTER | 4 | 30 | 120 | 10 | 1200 |
| INKJET PRINTER | 2 | 50 | 100 | 2 | 200 |
| PHONE CHARGER | 240 | 5 | 1200 | 4 | 4800 |
| | | | 19130 | 35 | 44665 |
| Total Fans in the Building | | | | | |
| GROUND FLOOR | 44 | 80 | 3520 | 9 | 31680 |
| FIRST FLOOR PLAN | 44 | 80 | 3520 | 9 | 31680 |
| SECOND FLOOR | 50 | 80 | 4000 | 9 | 36000 |
| THIRD FLOOR | 50 | 80 | 4000 | 9 | 36000 |
| | | | 15040 | 36 | 135360 |
| LIGHTS PRESENT ON A SINGLE FLOOR | | | | | |
| CLASS ROOM 1- 10 | 30 | 60 | 1800 | 3 | 5400 |
| RECEPTION + LOBBY | 6 | 60 | 360 | 7 | 2520 |
| STAFF ROOM | 2 | 60 | 120 | 5 | 600 |
| CORRIDOR | 14 | 60 | 840 | 7 | 5880 |
| | | | 3120 | 22 | 14400 |
| TOTAL WATTS REQ. | IN KILO WATTS | | | | |
| 46650 | 46.65 | | | | |
| ENERGY REQUIRED | | | | | |
| 45kw | | | | | |

The disparities in the energy consumptions of conventional and energy efficient equipments are clearly depicted in figure 4.71. As is clearly obvious, the most of the appliances use a large amount of energy. It's crucial to remember that even tiny reductions in energy use, while not particularly substantial on a small scale, are prerequisites that, when embraced on a big scale, will inevitably result in significant changes and advancements towards sustainable development.

**TRADITIONAL VS ENERGY SAVING**

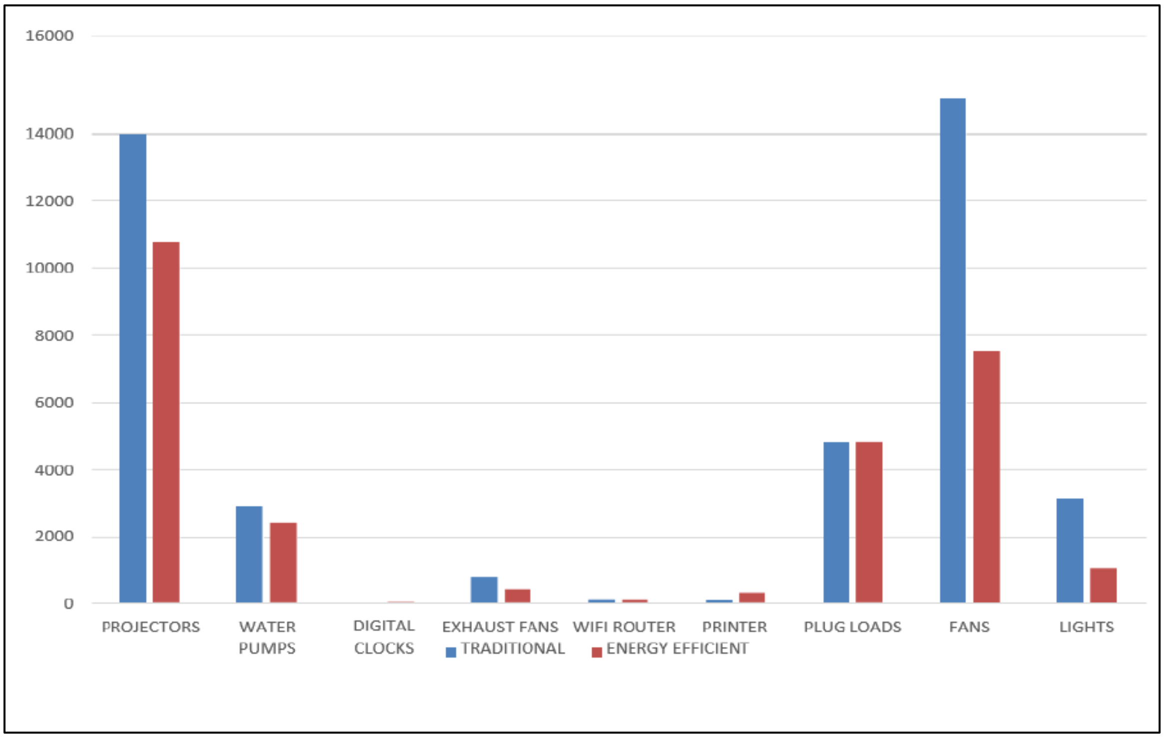


Figure 4.71: Bar graph depicting difference in energy consumption in Watts

### 4.4.1 Solar Energy Computation

1. Average sunshine = 5 – 7 hours/day
2. Panel capacity – 450 Watts
3. Energy required = 26.5 KW/day (As per table 4.3)
4. Energy required/Watts per panel = No. of Solar panels required.

⇨ 26467/450 watts per panel = 58.8

Thus **60** No's of solar panels are approximately needed.

With the same facilities, a conventional educational building will consume around **65 KW** of energy per day (Per Green Building Studio). The SketchUp modelled zero energy building with decreased number of energy efficient appliances delivers the same comforts & amenities with equal efficiency as that of the conventional appliances used in a traditional building. According to Table 4.3, the designed net zero energy educational building uses around 26.5 KW of energy daily, which translates to a **60%** reduction in energy use.

**Conventional vs NZEB Energy Consumption**

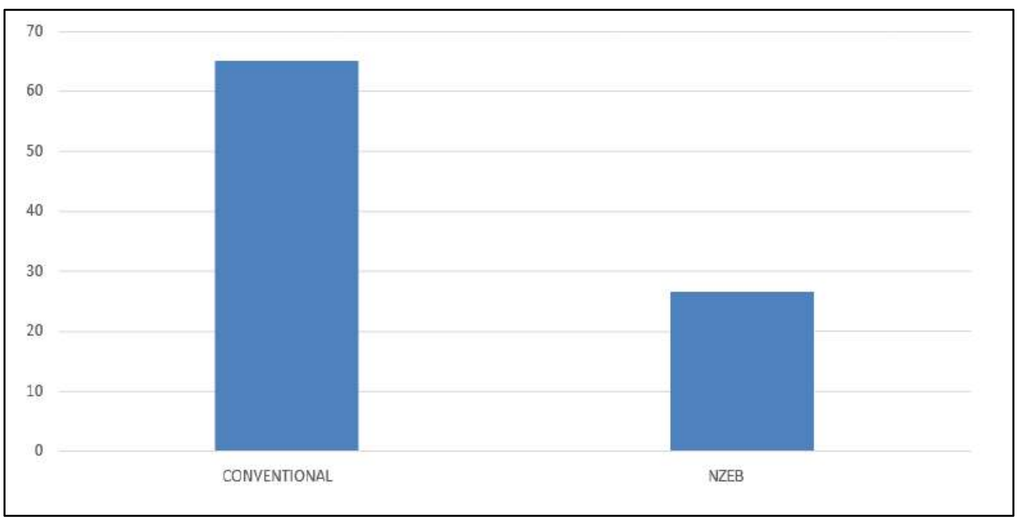


Figure 4.72: Depicting difference in energy consumption in Kilo Watts

### 4.4.2 Implementation of Rain Water and Grey Water Systems

**Water Resources**

| | |
|---|---|
| Total no. of students: | 1440 ≈ 1500 (approximately) |
| Water usage (Including water for drinking, flushing, washing): | 45 Litres / head / day (IS1172:1993) |
| Water Demand: | 67500 Litres/capita/day |
| Annual Water demand (Approximately, excluding non working days): | 12,352.500L |

The rain water collection for the selected building can be computed by:

Average Rain fall:

Min – 1200 mm/per year

Max – 2750 mm/per year

Total Roof Area = 1886 sq.m or 20110 sq. ft. (From building specifications)

30% of Roof Area = 566 sq.m

Average rainfall x Roof area = Rainwater/per year

Rainwater Collection per year:

Min – (566*1200) = 6, 79,000 litres / year

Max – (566*2750) = 15, 56,500 litres / year

The grey water obtained from the building is calculated by:

Water usage = 45 LPCD (IS 1172:1993)

Drinking purpose = 5 Litres

Flushing purpose = 25 Litres

Water Available as Grey Water = 15 LPCD

Annual Estimate = 2745 Litres (Excluding non- working days, total 183 working days)

The use of grey water for different purposes is depicted in figure 81 below.

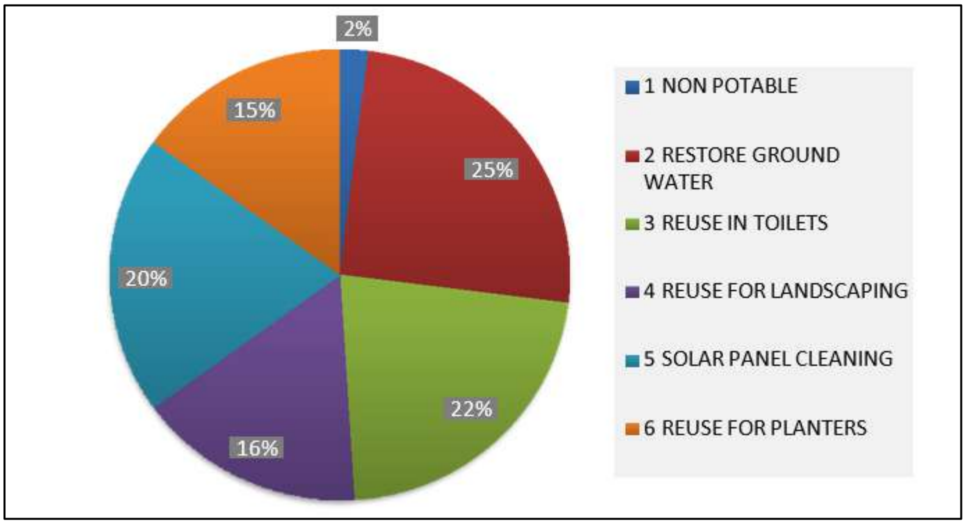


Figure 4.73: Chart depicting Grey water storage

The total water saved can be computed to:

Minimum – (6, 79,000 + 2745) = 6, 81,745 Litres (accounting to 5.51% of Annual water demand)

Maximum – (15, 56,500 + 2745) = 1559245 Litres (accounting to 12.62% of Annual water demand)

Hence on implementation of rainwater & grey water treatment systems, a minimum of **5.51%** and a maximum of **12.62%** of Annual water demand can be satisfied.

### 4.4.3 Estimate of Reduction in Cement and Sand

**Estimate for conventional building:**

Assuming M20 grade concrete with a safety factor of 1.57 and a ratio of 1:1.5:3 for the cement, sand, and aggregate. The specified plinth area is 81791 sq. ft.

Table 4.5: Estimation for conventional Building

| Description | Calculation | Quantity |
|---|---|---|
| Plinth Area<br>Assume<br>- 30% addition of concrete for construction of beams<br>- 5" (0.42') as roof thickness | 81791 sq. ft. | |
| | 81791 x 0.42 x 1.3 | 44657.89 cft |
| | Total Concrete Required | = 1264.570 $m^3$ |
| Cement | (1/5.5) x 1.57 x 1264.570 | = 360.977 $m^3$ |
| | 360.977 x (1440/50) | = 10397 bags of cement needed. |
| Sand | (1.5/5.5) x 1.57 x 1264.57 | = 541.46 $m^3$ |
| Coarse Aggregate | (3/5.5) x 1.57 x 1264.57 | = 1082.93 $m^3$ |

So, to construct the building using conventional materials, a substantial quantity of resources is needed. Precisely a total of 10397 bags of cement will be required, indicating the significant role cement plays in providing structural strength and stability to the project. Additionally, a substantial volume of sand, amounting to 541.66 $m^3$, will be essential for creating a solid foundation, ensuring proper compaction, and facilitating the construction process. Moreover, a cosiderable amount of coarse aggregate, measuring approximately 1082.93 $m^3$, is necaessary to provide stability and support in the concrete mix.

**Estimate for the Modelled Zero energy building:**

Here we replace 40% of Cement with Industrial sludge namely 10% of pulverised sludge and 30% of SSA.

So, 360.977 – (36.0977 + 108.2931) = 216.5862 $m^3$

216.5862 x (1440/50) = 6238 bags of cement needed.

Thus the total bags of cement needed are just **6238 bags** rather than **10397 bags.**

9% of Sand is replaced with Dry sludge.

So, 541.46 – 48.7314 = 492.7286 $m^3$

Thus the total amount of sand needed is just **492.7286 $m^3$** rather than **541.46 $m^3$.**

# Chapter 5

# Conclusions And Recommendations

## 5.1 Conclusions

When non-renewable energy resource inventories become depleted, humanity will soon be obliged to choose less energy intensive building methods in order to preserve the environment and cut carbon dioxide emissions. The novel aspect of the current project is that it suggests an integrated planning and design strategy for a net zero energy educational building that would run fully independently and apart from the urban networks. Also, it makes recommendations for the use of different industrial sludges in various building materials, which would serve the twin purposes of waste management and effective cost reduction for new construction.

This extensive research intends to:

- Offering architectural and planning solutions to increase the designed building's energy efficiency.
- Optimizing building orientation to the side of light with the predominant wind directions to counteract the detrimental effects of climate change on the building and thermal balance..
- Thermal mass flooring may be utilised to create a building with zero heat load..
- The use of LED lights has an advantage over conventional lighting in terms of energy saving..
- Ventilation systems to ensure improved interior air quality.
- Using industrial sludges in a variety of construction materials to fulfil demand for construction materials and further cut construction costs..
- Planting greenery has received more attention in an effort to create a healthy ecologically sustainable environment and to offer the required absorption of pollutants..
- The introduction of rain water harvesting and Grey water systems to recycle water.

## 5.2 Limitations

(i) The widespread perception that creating zero energy efficient structures is expensive is a constraining factor. Yet, analyses have indicated that the cost of energy efficient buildings is only 8–10% more than the average cost of normal structures, which is repaid in 10-15 years owing to the lower operating expenses.

(ii) The inclusion of industrial sludge into construction materials is still a relatively new idea, hence long-term consequences including toxicological effects, durability, and tensile strength of the various construction materials are still in their infancy. Furthermore, our proposal still has a glaring gap in the examination of how well the concrete with sludge inclusion meets the strength requirements, which must be filled before it can be used.

(iii) The project seeks to create a zero energy building with a few straightforward procedures, but with the data and results gathered, only a building with a gold LEED rating can be created, as opposed to the platinum LEED rating needed to create a zero energy building. At the pre-design phase, it is still necessary to monitor and assess how well zero energy buildings really perform in comparison to net zero energy objectives.

## 5.3 Future Research Direction

Based on the findings of the current study, recommendations for engineers and architects regarding alternate construction materials using industrial sludges, where the safety and building life have to be thoroughly evaluated, may be most beneficial for future research that might promote sustainable, energy efficient improved building design guidelines. Future possibilities should be used to continuously monitor and document the actual performance of the zero energy building. Further research should focus on the modeled building's air quality, the sustaining area's noise reduction, and a more thorough environmental audit.

Therefore, it is imperative to follow this construction trend and apply latest technologies to make buildings more energy efficient. By choosing to reduce energy waste from buildings, we can protect the planet's resources for coming generations.

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## List of Symbols, Abbreviations & Nomenclature

BLDC : Brushless Direct Current.

BTU : British Thermal Units.

CFL : Compact Fluorescent Lamp.

DHW : Domestic Hot Water.

DOE : United States Department of Energy.

EB : Electricity Board.

GHG : Green House Gas.

HVAC : Heating, Ventilation and Air Conditioning.

IES : Institute of Energy Studies.

ISO : International organisation for standardization.

ISSA : Incinerated Sewage Sludge Ash.

LCA : Life-Cycle Assessment/ Analysis.

LED : Light Emitting Diode.

LEED : A rating system for green building leadership.

LEED O+M : LEED for operation and maintenance of structure.

LPCD : Litres Per Capita per Day.

MED : Mechanical engineering Department.

NESE : Net Zero Site Energy.

NZEB : Net Zero Energy Building.

NZEC : Net Zero Energy Cost.

NZEE : Net Zero Energy Emissions.

NZSE : Net Zero Source Energy.

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|---|---|---|
| OECD | : | Organisation for Economic Cooperation and Development. |
| OPEC | : | Organization of the Petroleum Exporting Countries. |
| RCC | : | Reinforced Cement Concrete. |
| RHA | : | Rice Husk Ash. |
| SF | : | Silica Fume. |
| SSA | : | Sewage Sludge Ash. |
| SSP | : | Sewage Sludge Pellets. |
| TTWW | : | Tertiary Treated Wastewater. |
| ZEB | : | Zero Energy Building. |